THE

Indian Tea Association.

SCIENTIFIC DEPARTMENT

QUARTERLY JOURNAL.

PART IV.

1922.

Calcutta:
PRINTED AT THE CATHOLIC ORPHAN PRESS
3 & 4, PORTUGUESE CHURCH STREET.

1923.

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THE EFFECT OF MANURES ON THE CONSTITUTION OF THE TEA PLANT

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INTRODUCTION.

Within the past two decades the use of manures and artificial fertilizers has steadily increased in the tea gardens of North-East India. The chief object of manuring has been to increase the crop, and the success achieved in this direction can be partly gauged by the fact that the outturn per acre has been almost doubled in the past twenty years. Increased labour force, improved methods of cultivation and treatment have naturally also had a great influence in producing this increase.

While it is now a comparatively simple matter to increase crop by manuring and cultivation, it has happened in many cases that such increase has been obtained at the cost of an increased susceptibility of the plant to blight attack. Susceptibility to blight attack, for example, commonly follows the use of too heavy an application of nitrogenous manure alone.

On the other hand, the plant's susceptibility to disease has often been decreased by correct manuring, generally by the application of potash, lime and phosphates alone or in combination.

In the absence of good drainage, however, results have not been obtained, for it is difficult for manure of any type to exert its influence in a water-logged soil. In connection with water content of the soil and efficiency of manure, Shive (10), dealing with seedlings, has shown that the optimum manurial ratio is about the same, whatever the soil moisture may be, but the crop may be reduced by as much as 50% by making the water content double the optimum.

A study of the acid soils of Assam (2) has shown that the first necessity is generally the alleviation of acidity. An application of lime, potash or phosphatic manures brings about the desired result, but each in a different manner. The type of manure best suited to a soil depends naturally on the physical and chemical state of the soil.

Thus the primary effect for which a manure is added, *viz.*, increased available plant food, is not necessarily obtained in our soils until certain secondary reactions are finished.

Even when the secondary reaction of the manure has been realised, the primary action is not simple and straightforward. Hall (4) fully appreciated this when he proposed to analyse the soil by means of the plant, intimating that ordinary chemical analyses gave no true measure of the plant food in the soil. Some years later, Hall, Brenchley and Underwood (5) showed that there was some relationship between the amount of potash and phosphoric acid in the soil, and of these constituents in certain plants, but it was also shown that the variation between individual plants was often as great as that between plants grown in quite different soils.

Andrews (1), studying the mosquito blight of tea (*Helopeltis theivora*), has shown that if certain of the roots of an attacked bush are put into solutions of potash, the bush is able to throw off the attack in a few days. Solutions of phosphates fail to bring about this phenomenon.

It would thus appear probable that the degree of susceptibility to disease may be correlated with the composition of the leaf produced. Below is an account of experiments undertaken during the years 1918 to 1921, in order to ascertain how far the content of nitrogen, phosphoric acid and potash in the leaf of the tea plant could be altered by ordinary manuring. It is recognised, however, that other factors, such as the water content of the soil and the presence in the soil of substances other than those added as manure, will have a great influence on the plant's content of any particular substance, and therefore no very close correlation between manuring and plant composition can be expected except under very closely controlled conditions.

The work falls into two divisions, one dealing with sand cultures and the other dealing with fully grown tea bushes.

The Effect of Manures on Tea Seedlings.

In the earlier work on the effect of manures on tea seedlings grown in sand (6), groups containing 10 seedlings were treated with manures varying in their potash, phosphate and nitrogen content. It was shown that the phosphatic content of the seedling varied with that of the manure. The relationship between nitrogen and potash in the plant and that in the manure was shown to be obscure.

The next season (1921) fresh seedlings were grown. Only three different manures were added, and in each experiment there were originally 50 seedlings. By taking this number of seedlings it was anticipated that the effect of individual variability of the plants would be sufficiently diminished to make the average results of value.

Davis (3), studying the effect of different culture solutions on the weight of wheat seedlings, found that even by using 165 plants the arithmetic means gave a very incomplete idea of the value of the different manures. The curves of the frequency of distribution in two cases out of three practically overlapped. Only when the nature of the nutrient solution was entirely changed was any distinct difference in the weight of the crop observed.

Smith and Butler (11), studying the relation of potassium to the growth of plants, drew attention to the fact that potash manures greatly influence the potash content of the plant when potash is the limiting factor.

Accordingly, it was considered possible that, by treating seedlings with manures which were absolutely distinct, a significant change would be observed by analysing about 50 seedlings treated with each type of manure. It was also considered that the chemical constitution of a plant might respond more readily to different manuring than would the total weight of a plant.

The manurial solutions applied to the sand cultures were normal, potassic and phosphatic. The normal manure was based

on the well-balanced manure suggested by Knoop. The nutrient solutions were made from sodium nitrate, potassium chloride, superphosphate, magnesium sulphate and a trace of ferric chloride. Below is shown the constitution of the three solutions :

Manure.	N parts per million.	Water available.	
		Potash %.	Phosphates %
Normal	8·7	·0072	·00077
Potash	3·0	·0168	·00026
Phosphate	3·0	·0024	·00180

With the second and third solutions the potash and phosphate, respectively, are increased to make these constituents the predominating factors.

The seeds germinated in March and in April and were then planted in pure sand. After they were well established the cotyledons were removed preparatory to the addition of nutrient solution. The moisture content of the sand was kept at 15%, this figure having been noticed to give the best results with tea seedlings.

In September the seedlings were uprooted, dried and analysed. By this time only 31 of the 50 seedlings which received the normal manure were alive. Of those receiving the phosphatic manure 38 and of those receiving the potash manure 48 were still alive. The health and freedom from blight of the potash seedlings were marked throughout the experiment. With regard to flushing, the potash seedlings were again superior to the others, both with regard to size of new leaves and earliness of their formation. The seedlings receiving the phosphatic manure were the last to flush.

It may be remarked here that phosphatic manuring appears to improve the quality of tea. It is shown later that the phosphatic content of the leaf of the fully grown tea bush is not appreciably altered by phosphatic manuring ; hence the improved quality is probably due to some other change, and it is quite likely that the slowing up of the rate of flushing observed with seedlings may bring about this improvement.

The analyses of seedlings gave the following results :

Table showing Analysis of Tea Seedlings grown with Different Manurial Solutions.

Manures.	Ash %.	N %.	Phosphates %.		Potash %.	
			In dry leaf.	Ash.	In dry leaf.	Ash.
Normal	7·22	3·11	·503	6·97	1·53	21·20
Potash	7·53	3·25	·479	6·35	1·98	26·32
Phosphate	6·20	3·55	·530	8·40	1·72	27·40

The phosphatic manure increases the phosphate content of the dry leaf considerably but decreases the percentage of ash, whilst the potash manure increases the potassium content of the leaf.

The nitrogen content of the seedling is seen to be much greater in the plants receiving a phosphatic manure than in the others. This effect has been noticed with other plants, especially Leguminosæ (8).

There is considerable variation in the ash content of the different seedlings.

Hence it may be concluded that if potash or phosphates are made the controlling factor in the food of the tea seedling, the proportion of potash or phosphate in the seedling will be increased. This, however, does not hold with shoots plucked from fully grown tea bushes, as is shown below.

The Effect of Manures on the Constitution of the Tea Leaf.

In order to observe the effect of manures on the constitution of shoots from tea bushes, a plot of 252 bushes was selected. The plot was well drained and the soil, a sandy silt, fairly even. Weak bushes were not taken in the experiment. Each manured bush was separated from the next manured bush by three untreated bushes, the middle one of which was taken as the check bush. The lines were lettered A to I, and the bushes in each line numbered 1 to 28. The bushes from lines B, D, F, H were not analysed. The odd numbered bushes in rows A, C, E, G, I were analysed.

The manures were added in April of each year and, reckoning the nitrogen as N, the potash as K_2O and the phosphates as P_2O_5, each bush received manure at the rate of 90 lbs per acre made up in 6 quantities of 15 lbs. each. In the tables at the end the bush number, the amount of manure and the chemical analysis of the leaf are shown.

In 1919 the nitrogen was added as dried blood and in 1920 and 1921 as ammonium sulphate. The potash was added in all three years as chloride. In 1919 the phosphate was added as superphosphate and in 1920 and 1921 as bone meal.

The bushes were plucked weekly and each plucking was dried, and then at the end of each season the total crop was analysed. The yield from different bushes varied greatly and was in some cases almost as much as 2 lbs. green leaf in the season and in a few cases only half as much.

In the analysis of the leaves the phosphate was estimated as ammonium phosphomolybdate and the potash as perchlorate. The values given in the tables refer to percentages in dry leaf, for these figures probably have more significance than the percentage in the ash.

The conclusions drawn from the analyses will now be discussed. First the simple relationships will be considered.

(*a*) *Variation between Bushes.*—The variation shown by different check bushes is as great as that shown by bushes receiving manures of the most varied nature.

The tables below show the maximum and minimum values (excluding one or two exceptional figures which are very wide of the others) shown by different bushes. The values each year do not refer to the same bush.

The first table shows the variation between light pruned bushes and the second between collar pruned bushes. The light pruned bushes were pruned to two fingers of new wood each year and the heavy pruned were collar pruned in 1918, unpruned in 1919, cut to 6 inches above the collar in 1920 and again unpruned in 1921. The collar pruned bushes were plucked at 27 inches

from the ground and the top pruned leaving 6 inches above the pruning cut.

Variation between leaves from light pruned Check Bushes.

Year	Nitrogen %		Potash %		Phosphate %	
	Max.	Min.	Max.	Min.	Max.	Min.
1919	5·39	4·89	2·84	2·03	1·05	0·78
1920	5·98	4·85	2·86	2·09	1·07	0·76
1921	5·79	4·53	2·91	2·04	1 05	0·78

Variation between leaves from collar pruned Check Bushes.

Year	Nitrogen %		Potash %		Phosphate %	
	Max.	Min.	Max.	Min.	Max.	Min.
1919 unpruned ...	5·89	4·72	...	...	...	...
1920 6″ above collar ...	6·25	5·23	2·93	2·40	1·17	0·87
1921 unpruned ...	5·91	4·42	2·98	2·51	1·12	0·88

From this it will be seen that a comparison of actual values shown by differently manured bushes will give information which is always open to doubt. If individual bushes are followed through the three years it is possible to draw some conclusions.

(*b*) *Average Check Bush Values.*—The average shown by the light and collar pruned check bushes are given below :—

Average Analyses of Check Bushes.

	Nitrogen %			Potash %			Phosphate %		
	1919	1920	1921	1919	1920	1921	1919	1920	1923
Light pruned ...	5·05	5 57	5·23	2·63	2·53	2·81	0·90	0·90	0·90
Collar „ ...	5·27	5·82	5·30	2·88	2·64	2·79	0·95	1·01	0·99

The first point noticeable is that the collar pruned bushes give higher figures (except in the case of potash for 1921) than the light pruned bushes in spite of the fact that in 1919 and 1921 they are unpruned.

The nitrogen values rise during 1920 and fall again in 1921. The potash values fall in 1921 and then rise in 1921 to a value higher than that in 1919, so that high nitrogen corresponds with low potash. The phosphate values are fairly steady but show a slight general rise.

Now since cultivation, pruning and plucking have been the same over the three years so far as the light pruned bushes are concerned, the difference in these cases, at any rate, will be largely due to weather conditions. The year 1920 was one of very evenly distributed but light rainfall and this undoubtedly fostered good nitrate accumulation in the soil. This year was a good year for growth of tea. The year 1919 was the driest year of the three, in spite of heavy storms which would tend to minimise nitrate accumulation. Both 1919 and 1921 were poor years so far as the tea crop was concerned.

(c) *Nitrogen Values.*—As a general rule the light pruned manured bushes (irrespective of manure added) were richer in nitrogen than the check bushes during 1919. In 1920 and 1921 they generally dropped behind the check bushes. The values below are the means for the light pruned bushes compared with those of the checks.

Nitrogen Values.

	1919	1920	1921
Check Bushes	5·05	5·57	5·23
Manured Bushes	5·20	5 52	5·21

Thus on the whole the influence bringing about variation in nitrogenous content of the leaves was minimised by manuring.

The only bushes which were generally richer in nitrogen than the checks were those receiving 60 lbs. or more N. per acre. The table below illustrates

Nitrogen Values of Bushes receiving Manures rich in Nitrogen.

Manure lbs. per acre N.—P.—K.	Year.			Remarks.
	1919	1920	1921	
60— 0—30	5·35	6·23	5·91	Light pruned.
Nil	5·05	5·57	5·23	Check.
60—15—15	5·20	5·96	5·03	Collar pruned.
60—30— 0	5·31	6·05	5·09	„ „
75— 0—15	5·96	6·32	5·31	„ „
75—15— 0	5·91	6·06	6·17	„ „
60—15—15	5·30	5·92	5·66	„ „
Nil	5·27	5·82	5·30	Check.

In these cases nitrogen was evidently becoming a controlling factor in the food supply of the bush.

It is of interest to note that in the third year the influence of nitrogenous manuring is not so marked in some cases as in the first and second years.

(*d*) *Potash Values.*—The factors affecting the potash content of the leaf appear to be very complicated.

The bushes receiving manures rich in potash show no marked increase in that substance in their leaves and are generally poorer in potash than are the check bushes. The mean of the light pruned manured bushes may be compared with the mean of the checks.

Potash Values.

	1919	1920	1921
Check Bushes	2 63	2·53	2 81
Manured Bushes	2·57	2·48	2·79

Thus it is seen that the general variation is in close accordance with that of the check bushes.

During the first year the bushes receiving small doses of nitrogen were generally richer in potash than the checks whilst those receiving large doses of nitrogen were somewhat poorer in potash. During the second year this state of affairs was reversed. In the third year the deficiency was evenly distributed among the manured bushes irrespective of the manure.

The Influence of Nitrogenous Manures on Potash Values.

Manure	1919	1920	1921
15 lbs. N. and less per acre	2·99	2 39	2·82
More than 15 lbs. N „	2·39	2·58	2 79

(*e*) *Phosphate Values.*—The manures rich in phosphates have no apparent influence on the phosphatic content of the leaf and in many cases this value gradually decreases with time. On the whole the phosphates are steadier than either the potash or nitrogen content of the leaf.

The mean values of the manured bushes may be compared with the checks.

Phosphate Values.

	1919	1920	1921
Check Bushes	0·90	0·90	0·94
Manured Bushes	0·89	0·90	0·95

Thus there appears to be little general change in phosphatic content due to manuring.

(*f*) *Correlation between Constituents of the Tea Leaf.*—That there is a relationship between constituents of the ash of plants has been shown by Leoncini (7) and others. But the relationship is so complicated and the factors at work are so numerous that, before many observations have been made, it is futile to draw very definite conclusions in this direction.

It will be observed that the ratio between any pair of the three constituents, potash phosphate and nitrogen, generally varies in the same manner as shown by the average check bushes. This can be demonstrated by drawing up correlation tables after the manner suggested by Prof. Karl Pearson (9). The three tables shown below are drawn up from the values shown in Table I and Table III, excluding G line, at the end. All these values deal with lightly pruned tea bushes.

The correlation tables are made up as follows. Consider the potash-phosphates relationship. Taking the bush A I in Table I which receives 15 lbs. phosphates and 75 lbs. potash, it is seen that the potash value 2·36% occurs when the phosphate value is 0·88%. This relationship will be shown by an unit placed in the second "cell" down in the first column of the potash-phosphate table. The potash and phosphate values occurring in 1921 are expressed by an unit placed in the second "cell" down in the fourth column. And so with all the other values.

In drawing up the tables it was necessary to divide the "population," as the number of examples is termed, into significant classes. It was considered that differences of 0·2% for potash and 0·1% for phosphate content of the leaf ash were significant.

In Correlation Table I below is shown the relationship between potash and phosphate values in the leaf. The figures in italics are those corresponding to check bush values obtained from Table III at the end. The second figure is that obtained from the manured bush values, while the third figure is the total.

Correlation Table I.

Showing Correlation between Potash and Phosphate Values in Manured and Unmanured Tea Bushes.

Phosphate.		Potash. Less than 2·4%	2·4 to 2·6%	2·6 to 2·8%	2·8 to 3%	More than 3%
	0·7 to 0·8% ...	1 / 2 } 3	2 / 2 } 4	3 / 2 } 5	1 / 0 } 1	0 / 0 } 0
	0·8 to 0·9% ...	3 / 8 } 11	6 / 4 } 10	13 / 8 } 21	0 / 3 } 3	2 / 4 } 6
	0·9 to 1·0% ...	5 / 3 } 8	4 / 0 } 4	10 / 12 } 22	6 / 5 } 11	1 / 0 } 1
	More than 1% ...	0 / 1 } 1	2 / 0 } 2	4 / 3 } 7	5 / 2 } 7	3 / 1 } 4

The total "population" of the table is 131. The number of check or manured bushes separately is insufficient to give any accurate correlation values.

From the table, the mean square contigency is calculated, and from this value the coefficient of contingency may be calculated by means of the formula

$$C_1 = \sqrt{\frac{S}{1+S}}$$

where S = mean square contingency.

The coefficient of correlation, C_2, was also calculated from the mean contingency (9).

The values obtained are as follows :—

Mean square contingency = 0·179, coefficient of contingengy $C_1 = 0{\cdot}39$.

Mean contingency = 0·157, coefficient of correlation $C_2 = 0{\cdot}42$.

In considering the correlation between the nitrogen and potash or phosphate content of the leaf the question of significance of nitrogen values presented some difficulty. It was finally decided to take five values differing by 0·25%, varying from 4·75% to 6%, together with a high and low value, making seven values in all. As before, four phosphate values were considered a reliable range.

Below is shown the nitrogen-phosphate correlation table. The separate numbers in each cell have the same significance as in Correlation Table I.

Correlation Table II.

Showing Correlation between Nitrogen and Phosphate Values in Manured and Unmanured Tea Bushes.

Phosphate.		Nitrogen.						
		Below 4·75%	4·75 to 5%	5 to 5·25%	5·25 to 5·50%	5·50 to 5·75%	5·75 to 6%	Over 6%
	·7 to 8%	1 1 } 2	2 1 } 3	0 2 } 2	3 1 } 4	0 0 } 0	0 0 } 0	0 0 } 0
	·8 to 9%	1 2 } 3	3 3 } 6	7 4 } 11	3 9 } 12	6 4 } 10	2 1 } 3	0 2 } 2
	·9 to 10%	4 2 } 6	4 4 } 8	4 4 } 8	9 6 } 15	5 4 } 9	2 0 } 2	0 0 } 1
	Over 1%	1 0 } 1	1 0 } 1	3 1 } 4	2 5 } 7	2 0 } 2	4 1 } 5	2 1 } 3

The mean square contingency, the mean contingency and the corresponding coefficients of contingency and correlation values are shown below :—

Mean square contingency = 0·173, coefficient of contingency = 0·38

Mean contingency = 0·139, coefficient of correlation = 0·40

The Correlation Table of the nitrogen-phosphate values presented many difficulties. The correlation values, as calculated from the mean square contingency and the mean contingency, showed considerable variation. By varying the grouping of the nitrogen and potash, a range of correlation and contingency coefficients was obtained.

The correlation is of the same order as shown by the potash and phosphate values.

Below is shown the Correlation Table for nitrogen and potash.

Correlation Table III.

Showing Correlation between Nitrogen and Potash Values in Manured and Unmanured Tea Bushes.

Phosphate. \ Nitrogen.	Below 4·75 %	4·75 to 5 %	5 to 5·25 %	5·25 to 5·50 %	5·50 to 5·75 %	5·75 to 6 %	above 6 %
Below 2·4 %	2 1 } 3	0 1 } 1	1 5 } 6	2 4 } 6	4 3 } 7	0 0 } 0	0 0 } 0
2·4 to 2·6 %	0 1 } 1	3 2 } 5	3 1 } 4	4 0 } 4	2 0 } 2	2 1 } 3	0 0 } 0
2·6 to 2·8 %	4 0 } 4	4 5 } 9	7 5 } 12	0 9 } 18	3 2 } 5	3 0 } 3	0 0 } 2
2·8 to 3 %	1 3 } 4	1 0 } 1	0 2 } 2	1 3 } 4	3 2 } 5	3 3 } 6	1 0 } 1
Above 3 %	0 0 } 0	2 0 } 2	1 2 } 3	1 1 } 2	1 0 } 1	1 0 } 1	1 1 } 2

The mean square contingency = 0·247

Coefficient of contingency = 0·45

Mean contingency = 0·198

Coefficient of correlation = 0·52

The grouping is still unsatisfactory, but it is unjustifiable to arrange the tables so that the variation in the nitrogen or potash values ceases to be significant.

By varying the gradation of nitrogen and potash, the following relationships were obtained. The nitrogen variation was always kept at 0·25 % and the potash at 0·2 %, the change being made in the magnitude of the upper and lower limits :—

Nitrogen.		Potash.		Coefficient of	
Upper limit.	Lower limit.	Upper limit.	Lower limit.	Contingency.	Correlation.
6 %	4·75 %	3 %	2·4 %	0·45	0·52
5·75 %	4·75 %	3 %	2·4 %	0·40	0·61
5 75 %	4·75 %	3 %	2·2 %	0·47	0·67
6 %	4·75 %	3 %	2·2 %	0·51	0·70

The Significance of the Correlation Factor.—The quality of the tea made in any tea garden depends on many factors—environmental, meteorological, personal, etc. It has often been observed that the greater the crop the poorer the quality of the tea produced. Now suppose that every time the crop was doubled the quality was halved, then we could say that quality depended absolutely on the size of the crop. In this case the relationship would be causal. We know, however, that many other factors, beside crop, influence the quality of the tea. Suppose that of the total influences bearing on quality one half were due to the size of the crop, then we should say that the correlation between crop and quality is 0·5. If the crop wholly dominated quality, the correlation would be 1, and in the case of there being no domination at all, correlation would be zero.

If we argue still further we ask the question—why should crop influence quality ? This question can be answered in part. The more vigorous the leaf growth, the less the tannin content of the leaf and the less concentrated the cell sap. Now concentrated sap and a high tannin content make for quality in tea hence it is simply because some of the qualities which are influenced by rapid growth are also connected with good quality in tea that there is a correlation between crop and quality. Correlation in this case suggests parallelism, a case of factors in common.

Reverting now to the correlation between the constituents in the tea leaf we see that about 40% of the influences (correlation 0·42) at work on the potash and phosphatic content are the same. If the potash increases, the chances are 4 to 10 that the phosphates will also increase. The correlation in this case is positive.

With nitrogen and potash or phosphates a similar correlation holds although in this case an increase in nitrogen brings about a decrease in potash or phosphate. The correlation in this case is negative.

Now correlation between plant constituents is only a measure of the relationship between the variation of the constituents. Thus, if the potash values were always 2·5% and the phosphate values always 0·9%, the correlation would be nil. The idea of correlation embodies change. By making the grading of our classes or arrays of constituents coarse enough we can arrange our table so that all the "population" occurs in one "cell." All the table then tells us is that certain constituents invariably occur in the leaf. The relationship in this case is casual.

The importance of correlation between the plant constituents can be appreciated in problems where an attempt is made to increase any particular constituent. Thus it is believed that potash as a manure will be an important factor in the solution of the Tea Mosquito Blight problem.

Although it has been shown that ordinary doses of potash do not appreciably increase the potash content of the leaf it is highly probable that large doses would do so. But at the same time the phosphatic value would be increased. Hence it will be most difficult to influence the ratio of potash to phosphate in the leaf.

Conclusions.

The following conclusions may be drawn :—

(*i*) Heavy pruning increases the nitrogen content of the leaf and tends to increase the potash and phosphate content.

(*ii*) Manures up to 75 lbs. per acre in the case of potash and phosphates have no apparent influence on the potash

and phosphatic content of the leaf. Nitrogenous manures of over 60 lbs. increase the nitrogenous content of the leaf.

In connection with this second point it must be remembered that Tocklai soils are very deficient in nitrogen and hence this constituent may much more easily become the limiting factor than either potash or phosphates. If enough potash or phosphates were added to make either the controlling factor then it is highly probable that these constituents would be influenced.

In considering compound relationship of the constituents of the tea plant, it appears that potash and phosphate vary together, but that nitrogen varies inversely as the other two. Good growth (as in the year 1920) goes with a high nitrogen content and low potash.

TABLE I

Showing the Variation in Potash, Phosphate and Nitrogen Content in Leaves of Manured Light-pruned Tea Bushes.

Percentage on dry leaf are given.

Bush No.	Manure lbs. per acre N—P—K.			Potash %			Phosphate %			Nitrogen %		
				1919	1920	1921	1919	1920	1921	1919	1920	1921
A 1	0	15	75	3·30	2·36	2·88	0·90	0·88	0·86	5·57	6·14	5·84
A 5	0	30	60	2·71	2·63	2·94	0 85	0·87	0·87	5·13	5·71	5·32
A 9	0	45	45	3·21	2·74	3·22	0·89	0·89	0·81	5·44	6 02	5·43
A 13	0	60	30	2·90	2·64	2·97	0·86	0·94	0·93	4·69	4·78	4 66
A 17	0	75	15	2·73	2·23	2·40	0·85	0·79	0·88	5·33	5·29	4·85
A 21	15	0	75	2·66	2·07	2·68	0·77	0·78	0·80	4·77	5·09	4·91
A 25	15	15	60	3·73	2·50	2·83	0·90	0·78	0 95	5·01	5·98	5·21
C 27	15	30	45	2·79	2·32	2·98	0·88	0·85	0·91	5·70	5·73	4·63
C 23	15	45	30	2·64	2·28	2·66	0·88	0·95	0·99	5 45	4·76	5 30
C 19	15	60	15	2·67	2·29	2·75	1·07	0·85	0·93	5·35	5·38	4·82
C 15	15	75	0	2·61	2·29	2·66	0·97	0·98	1·01	5·27	5·65	5·43
C 11	30	0	60	2·20	2·34	2·79	.....	0·91	0·92	5 21	5·45	5·08
C 7	30	15	45	2·29	2·27	2·73	1·24	0·88	1·00	5·14	4·63	5·46
C 3	30	30	30	2·86	2·38	2·98	.....	0·84	1·00	5·23	5·73	5·60
E 25	30	45	15	2·38	2·62	2·75	0·89	0·99	1·03	5·26	5·22	.....
E 21	30	60	0	1·90	2·45	2·62	0·86	0·88	0 98	5·17	5 11	.....
E 17	45	0	45	2·05	2·66	.....	0·88	0·76	.....	5·04	5·13	4·38
E 13	45	15	30	2·52	2·62	2 81	0 87	0·95	1·00	4·98	6·04	5·85
E 9	45	30	15	2·75	2·62	2·69	0·83	0·93	0·96	5·37	5·30	4·91
E 5	45	45	0	2·49	2·81	2·91	0·60	0·93	1·09	4 66	5·48	5·42
E 1	60	0	30	2·61	3·06	2·85	0·84	0·04	1·05	5·35	6·23	5·91
.....	Average Check.			2·63	2·53	2·81	0 90	0·90	0·94	5·05	5·57	5·23

TABLE II

Showing the Variation in Potash, Phosphate and Nitrogen Content in Leaves of Manured Collar-pruned Tea Bushes.

Percentage on dry leaf are given.

Bush No.	Manure in lbs. per acre N—P—K.			Potash %			Phosphate %			Nitrogen %		
				1919	1920	1921	1919	1920	1921	1919	1920	1921
G 27	60	15	15	2·45	2·68	2·86	0·82	1·01	0·98	5·20	5·96	5·03
G 23	60	30	0	2·54	2·83	2·83	0·84	0·91	1·00	5·31	6·05	5·09
G 19	75	0	15	2·65	2·73	2·58	0·85	0·96	0·93	5·96	6·32	5·31
G 15	75	15	0	3 25	2·75	2·82	1·03	1·09	1·13	5 91	6·06	6·17
I 1	60	15	15	....	2·77	2·66	....	1·14	1·04	5·30	5·92	5·66
....	Average Check			2 88	2·64	2·79	0 95	1·01	0 99	5·27	5·82	5·30

TABLE III

Showing the Variation in Potash, Phosphate and Nitrogen Content in Leaves of Unmanured Tea Bushes.

Percentages on dry leaf are given.

Bush No.	Potash %			Phosphate %			Nitrogen %		
	1919	1920	1921	1919	1920	1921	1919	1920	1921
A 3	3 21	2·29	2·64	0·91	0·85	0·78	5·29	5·56	5·40
A 7	3 12	2·53	2·62	0·80	0·79	0·79	4·91	4·97	5·81
A 11	2·48	2·33	...	0·86	0·76	...	5·13	4·68	5·69
A 15	3·07	2·60	2·75	1·00	1·05	0·93	5·25	5·39	5·12
A 19	2 72	2 65	2·43	0 89	0·91	1·02	5·10	5·16	5·03
A 23	2·75	2·56	2·71	0·87	0 88	0·89	4·91	5·73	4 61
A 27	2 65	2·41	2·79	0·83	0·93	0·86	5·39	5·80	5·13
C 1	2·72	2·20	2·75	1·64	0·81	0·97	5·36	5·52	5·79
C 5	2·60	2·09	2·51	0·97	0·87	0·92	4·98	5·58	5·45
C 9	2·14	2·19	2·91	...	0·97	0·93	5·03	5·59	5·06
C 13	2 64	2 68	2·90	0·84	0·88	0·94	5·11	5·98	5·67
C 17	2 67	2·49	2·81	1·00	0·83	0·93	4·89	5·84	5·48
C 21	2·52	2·36	2·74	1·05	0·91	0·89	5·17	5·39	5·11
C 25	2·79	2·30	3 30	0·86	0 95	1·05	5·02	5·35	6·20
E 3	2·58	2 54	...	0·92	0·93	...	4·87	5·74	4·53
E 7	2·84	2·64	3 04	0·98	0·95	1·10	4·85	5·71	4·97
E 11	2·52	2·86	2·68	0·78	1·07	0·91	5·25	5·80	5·27
E 15	...	2·41	2·74	...	0·88	0·99	4·81	5·40	5·36
E 19	2·03	2 75	2·84	0·95	0·83	1·00	4 56	5 57	4·64
E 23	2·09	2·60	2·72	0·94	0·86	1·02	5·19	5·47	5·10
E 27	2·44	2·61	2·65	0·89	0·89	0·91	4 98	5·68	4·58
G 13	2 93	2·93	2·92	0·91	1·06	1·06	5·54	6·11	5·57
G 17	3 45	2·87	2·86	1·31	1·17	1·06	5·89	5·96	5·91
G 21	2·61	2·62	2·74	0·75	0·90	0·94	5·38	5·31	4·42
G 25	2·53	2·93	2·77	0·81	1 09	1·05	5·01	5·74	4·43

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ANALYSES OF TYPICAL TEA SOILS

BY

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While a planter is certainly not expected to make analyses of his soils, it is useful to him to have some idea of the meaning of the figures of analysis when obtained. He will then be able to understand the reasons for treatment advised, and to modify it to suit his own conditions without loss of efficiency.

The accompanying tables show analyses of tea soils chosen as representing the chief types of soil found in North-East India.

The first table shows the sandier soils, which naturally contain relatively high percentages of sand and relatively low percentages of clay. The term "sandy" can of course only be used relatively. The first two would be better called sandy loams. These two are of much the same physical composition (as can be seen from the mechanical analyses) and are physically excellent soils for tea, being mainly sand with sufficient clay to bind them nicely and give that "crumb" in the soil which signifies good tilth.

No. 1 is an old teelah which has been badly washed although now fairly well protected by bunds. No. 2 is an unsually rich virgin soil from the same neighbourhood. Originally they must have been the same chemically as well as physically. Note now the differences between the two chemical analyses, particularly in "loss on ignition" (total organic matter), "Grandeau organic matter" (soluble humus) and in nitrogen. It is in consequence of these differences that No. 1, for many years under normal Cachar pre-slump plucking, gave only about five mds. pucca tea per acre. This was certainly cheaply produced, but had the soil maintained in the condition of No. 2 it would be giving 15 mds. of similar tea.

Having reached its present low condition of fertility, No. 1 soil will probably not drop further very rapidly, but white ants are doing serious damage to the poor bushes, and a certain number of bushes die out annually from Thyradaria tarda, a fungus disease of the stem usually serious only on weak plants.

Money is being wasted on cultivating vacancies and non-yielding bushes, while the smallness of the crop increases plucking and manufacturing cost per lb.

In these days of shortage, is the labour being used to most advantage? Mechanically it is a beautiful soil. Money wisely spent on infilling and manuring would certainly yield a big return.

What manure does the soil want? The selection is easy when we can compare with a good soil mechanically similar and in the same district.

The acidity is too high, and the phosphoric acid not as high as it should be. We must add a little lime and phosphoric acid, particularly as it is absolutely essential that we shall grow good green crops.

Potash is probably high enough. It would be well to run an experiment to see what potash manuring would do, but on the analyses we should judge potash manuring to be not essential and so will save expenditure on that item.

Above all we want organic matter and will add it in every way that the local conditions make possible, taking into account distance from lines and jungle.

Any cattle manure available will of course go on. Green jungle may be near enough to cut and carry on. Generally, however, we have to rely on green manuring and will do as much as we have labour to manage.

Prunings of course will never be burnt but always hoed in, except heavy prunings which are dangerous where there are root diseases.

With our organic matter we have added a lot of nitrogen, but as we have not unlimited labour we must supplement it by

artificials. This soil has so much sand that it can decompose the less readily available manures (particularly when lime has been added) and it contains enough clay to carry the most readily available. We can choose annually the cheapest form of nitrogen which is known to be efficient.

No. 3 is a real sand, one of the coarsest in tea.

Under Bishnauth rainfall it does splendidly under tea. This particular soil has done so for many years, but is now showing signs of deterioration.

On a sandy soil the bushes have a large root range and explore an enormous volume of soil for food. What food there is, too, is in a more available condition than on a heavier soil. Water does not lie on such soils, and with a few deep drains to keep down the rains water-level these sands do well, because the soil aeration is automatically good.

Sands, however, make such good use of added manure that it is always a pity not to manure them ; and in this particular case the soil is getting a bit deficient in some respects. Notice particularly the potash. Nitrogen and organic matter are pretty good for such a light soil but should be at least maintained.

The main trouble with such soils is not their chemical but their physical properties.

Water moves very rapidly through a sand, but will only lift water by capillarity for a comparatively short distance. As the surface dries so more water comes up rapidly from below to be evaporated away, while a sand cannot draw on the stores of water in the deep subsoil. In consequence the water content of a sand is very seriously reduced during a drought. In 1919 much tea on similar soils died right out, while much of what remained alive was so weakened that it was very seriously attacked by blights, brown blight, red rust, *Thyradaria tarda.*

This year's early dry period again did damage.

A coarse sand is a splendid soil where the cold weather water-level is comparatively high, and the rains water-level

comparatively low. The rains water-level must be low in order to get roots down near the soil which will remain moist in the dry season.

A position near a river bank, where the water remained about 8 feet from the surface, would be ideal. Where such is not the case, every effort must be made to conserve the water in the soil during the dry season, by keeping the surface clean of jungle (which pumps out water) and by keeping a loose surface mulch to hinder evaporation.

In the Jorhat district the water-level is commonly pretty high, and the typical soil is, like No. 5, mainly made up of fine sand with little coarse sand. Such soils, while coarse enough to permit rapid percolation of water (hence good aeration), are fine enough to be able to lift water from a much greater distance than No. 3 can. Even No. 4, which is representative of the Jorhat coarser soil, is still fairly good in this respect.

No. 5 represents the geologically older soil of the district, while No. 4 is probably a newer deposit.

The newer deposit contains much more lime (hence the low acidity) and more phosphoric acid. The newest deposits near the Dessoie River are occasionally actually alkaline to litmus and very rich in lime. The newer deposits are distinguished by a very low content of organic matter. They have not been long enough in position to collect a good supply of organic matter from jungle residues in the surface soil, and are therefore particularly infertile. Tea does not flourish in a soil too rich in lime, neither does it do well in soils too deficient in organic matter. In consequence new alkaline deposits, when planted, are frequently afterwards abandoned, although jungle (particularly leguminous jungle) grows well. There are many such cases in the Dooars. There are cases where tea does quite well in alkaline soils if only the organic matter is sufficiently high, but on the whole a soil which turns red litmus blue is better avoided for tea. No soil could retain much lime under our rainfall for long, and an alkaline soil is either very new, very impervious to water, or both.

No. 4, although for all practical purposes neutral to litmus, now does very well, but it required several years of addition of organic matter to change it from a distinctly poor soil. The particular test* which measured this soil's lime requirement at 245 parts per million is one which exaggerates enormously the amount which should actually be applied. The acidity figures are only of value in a comparative sense, and would have no value at all but for one's experience of results on other soils, of which we have analyses.

No. 4 certainly wants no more lime, but No. 5 has too high an acidity for such a light soil, and one would guess it to need some lime. It has, in fact, shown good results from liming.

Being sandy, No. 4 is rich enough to do fairly well without manuring in this district; but will certainly give results from additions of nitrogen, phosphoric acid and a little potash too, and can do with all the organic matter it can get. On No. 5 the crop was being very seriously limited by its need for phosphoric acid until some was added. Otherwise it is quite well off, but still gives value for additional nitrogen, organic matter, and a little potash.

On a sandy soil it is a safe rule to add potash, unless it is pretty certain that it is not needed. Even if little additional crop is obtained in the first year, it helps to keep the bush in better condition.

No. 6, although it contains no more clay than No. 1, is mainly composed of silt, and not sand. Silt behaves like a very fine sand, but when containing a significant quantity of clay and very little sand as No. 6 does, silt soils are most unpleasant to work, unless well provided with organic matter. They pack down tightly so that they are very little aerated, and they behave like solid stone in dry weather. They are generally on the poor side chemically. That is easy to remedy, but it is not easy to remedy the defects of their mechanical composition.

In the case of No. 6 lime will assist, because it will help to flocculate the clay which is present. In many soils of much the

* Albert method as modified by Lyon & Brizzel.

same nature, which contain little clay but much fine silt, we cannot hope for much from lime. But in all such cases our main hope lies in getting in organic matter, and it must be got in deeply. We must trench in and deep hoe in all the green stuff and cattle manure, and prunings that can be obtained.

Drainage, of course, must be close and deep. On account of the close packing of the soil particles, the soil space is already too small. We cannot afford to let any of it be occupied by excess water to the exclusion of air.

Even with as much work as is normally possible on such soils they seem to get hardly any better for years; but after, say, four or five years a manager does admit that his particular bad section is looking a bit better and giving a bit of leaf. Improvement then becomes more rapid if the treatment is maintained.

No. 7 is an example of the rich, dark-coloured sand common in the Dooars.

It is even more coarsely sandy than the Bishnauth sample, yet is much richer than the average, very-much-heavier soil. It compares well with the remarkably rich virgin soil from Cachar (No. 2).

Yet No. 7 is among the oldest of the Dooars gardens, and the patches of the same soil (which covers a large area) that have not been so long under tea are even richer.

These sands are apparently enriched by old surface soils washed down from the Darjeeling hills.

Looking at the figures for No. 7 one sees that it is well off in every respect, except that it is rather low in potash and is for such a light soil excessively acid. Such a soil has given good results from potash, and, judging by planters' reports, lime also benefits sands of this character.

The curious thing is that they also give good results from nitrogen, although from analyses one would judge them to have ample. Apparently, the nitrogen is present in forms only slowly available to plants. Further experiments may show that the final result from too much nitrogen is to weaken the bush and lay it

more open to blight attack, but soils of this type which have received light dressings of oilcake for years now certainly look much better than more neglected soils, and give good yields of good quality tea. These soils have always been bad for mosquito blight, but are now becoming relatively better.

Treatment of the soil for mosquito blight has only just reached the experimental stage, but we have a fine lot of experiments being very well run, particularly in the Dooors, and we shall know something about the subject when these experiments have run for some years. So far one can only say that a certain amount of success has often followed the use of potash and lime, and that anything which weakens the bush increases the bad effect of any blight. On sands weakness following drought is a reason for increased loss from mosquito. Present-day drainage and cultivation would certainly tend to improvement in this direction, and the relative improvement of these sands possibly may be correlated with improvement in work.

Clay Soils.

As a contrast to the sands just examined, take the figures for the clay soils on Table III.

Here you will notice that the mechanical analyses show very little sand but large percentages of fine silt and clay. The examples have all been chosen from the same neighbourhood, because, when the climate is the same for each, the influence of the soil is more directly seen on the crop obtained.

No. 16 is the stiffest soil of which we have record. When dry, a pickaxe could hardly cultivate it ; when wet, it is like glue. Had this soil been deep, it is probable that it could not have been kept in cultivation. Yet it is, compared to the sands, very rich chemically, even in respect of organic matter, the most active agent in improving a clay. When first planted, the young tea certainly grew but very slowly even in the virgin soil, and took several years to get through one foot of this clay into the subsoil of pure rich peat. Then the tea went ahead.

The clay is rich and would be worth carrying on to a sandy soil as manure, yet is so heavy that, but for its peat subsoil, it would probably prove a very poor soil for tea.

It is clear, then, that the figures given by chemical analysis are of no use except when considered together with the mechanical analysis.

Although rich this particular clay is a bad soil, simply because so impervious to water and air.

No. 2 is physically much less clayey, but is still quite heavy enough to be a real bad soil when the organic matter content is low.

"Loss on ignition" measures not only the combustible organic matter in a soil but also the water driven off from soil minerals by heat.

The "Grandeau" organic matter is a safer guide to the amount of useful organic matter in a soil.

Note the "Grandeau" figure in No. 17. It would be low for a sand, and for a clay it is altogether inadequate.

The nitrogen at ·116% would be good enough for a sand, but indicates a very poor clay. Phosphoric acid and potash are on the low side and need increasing, but the chief need of this soil is a better physical condition. It would be better if it had more coarse sand, but one could not, of course, afford to carry on enough sand to make any difference. To increase the sand by 1% in the top foot would require about 20 tons of sand per acre. The burial of broken earthenware pots such as Howard advises for Bihar indigo soils would certainly be beneficial, but again the cost of such treatment would be prohibitive.

Villagers often do make a big improvement in such soils by scraping into heaps with rubbish, and burning the heaps when dry. The heating of the soil and the formation of lumps of red burnt ballast both greatly benefit the soil's physical condition. Such treatment might be actually carried out on tea land before planting, but is of course impossible on planted land.

In practice, we are limited to the use of lime and organic matter. The use of lime is always to be advised on a clay (even if the acidity of the soil is considered to be doing no harm), because it flocculates the clay and so increases the soil space and allows freer percolation of the soil by water and air.

Organic matter acts in much the same way, and even a little makes a difference.

This soil then could be considerably improved by a course of treatment including lime, green crops (with phosphates) and added nitrogen. Potash is probably not required. With a clay one follows the rule that potash is not applied unless there is evidence of its need. Exception to this rule may be made in the case of cut-back tea.

With all heavy soils it is absolutely essential that drainage must be thoroughly efficient. Without that, no treatment can have much effect.

Nos. 18 and 19, in spite of their high percentages of fine silt and clay, grow beautiful tea. Note their high contents of organic matter.

No. 18 would, no doubt, benefit from phosphatic manure, and the organic matter content of both needs maintaining by occasional green manuring.

Otherwise they should require nothing for many years, although lime would probably do good, and should, at any rate, be tried experimentally.

No. 18 is a teelah soil. No. 19 is a drained bheel, but on account of its high percentage of clay we shall not expect it to suffer the deterioration which has set in on the true peats and peaty sands of the district.

Bheel Soils or "Humus" Soils.

When the amount of organic matter in a soil is very high its influence on the texture of the soil is so great as to make almost negligible the effect of whatever sand, clay, etc., may be present.

The organic matter in No. 19 is high, so high that a soil which with normal organic matter would be a poor one is actually one of the very finest tea soils in India.

No. 19 is a bheel soil in the sense that it is a flat formed by draining a shallow lake, so also are 16 and 17.

No. 16 is peat-bheel in the subsoil, but the peat first accumulated in it has been covered by a later deposit of clay.

No. 20 is an example of a real peat, a little mixed with soil on the surface and becoming pure peat underneath. Note the extraordinary richness of it. Many samples of cattle manure are not so rich.

The peats in this country are not preserved moss as they are in Britain, but at our higher temperatures decompose to a large extent into useful plant-feeding humus. Newly planted peat bheels yield enormous crops. Unfortunately they do not last.

No. 21 is still described by the Manager as a peat soil. It is probable that it once was so, and there is still real peat at only one or two feet below the surface.

The analysis of the present surface soil is that of a very rich sand. It resembles in many respects a garden soil that has for years been overmanured with stable manure. It does not "bind" at all. In the dry season a light cane can be pushed right through, without effort, up to the handle.

This soil has lost its sticky colloidal fine particles, and is of such a loose open texture that its water-lifting power is very limited. One sees such soils dust-dry at 1 ft. from the surface when water is running at the bottom of 3 ft. drains. Roots never penetrate far into a peat, and in consequence the tea on a deteriorated bheel is left high and dry in the cold weather, although possibly only a few feet above water.

The mosquito and other blights on No. 21 take most of the crop.

True peats deteriorate in very similar fashion.

Note the "coarse sand" in No. 20. Seven per cent. of this soil remained on the sieve used to separate out coarse sand. When this "coarse sand" was burnt nothing but a very light ash remained. It was not coarse sand but large particles of vegetable matter.

In deteriorated peats the "colloidal" organic matter has largely disappeared, leaving particles of organic matter of comparatively large size, and they can no more lift and hold water than the humus sands like No. 12.

Water commonly runs through bheels in the cold weather. A lot can be done by keeping up the level of the water in the drains to 24″ or even 18″ inches from the surface by a series of weirs. This is because "film water"—water lifted by capillarity—is not sufficient for the needs of a plant on these curious soils, which not only cannot retain water but also need a lot.

Note the water content of No. 2. 62 per cent. of the stuff in the sample box was water, but the sample was not unduly wet.

A soil which is normally mainly water naturally contracts as it dries and when to this loss is added the organic matter washed away and oxidized away it can readily be appreciated how rapidly such soils may sink under the influence of drainage and cultivation.

Many still good peats are out of cultivation merely because they have fallen below the level of the drainage outfall. A peat requires shallow, close drainage, and the water level must be kept up in the cold weather.

The theories on other possible treatments of peats are fascinating, but there is no space to deal with that about which nothing definite is known. One garden only is experimenting in this direction. We shall welcome offers to undertake further experiments.

Medium Soils.

The special properties of the sands, clays, and humus soils having been examined; those of the medium soils may be

fairly well guessed at, since they may be regarded as mixtures of sand, clay, and humus in various proportions.

No. 8 differs only from Nos. 1 and 2 in having a little more clay.

No. 9 being evenly graded, that is containing a fair quantity of particles of all sizes, will tend to pack tightly and set hard. It is quite well off in organic matter which keeps it good and is otherwise rich except that it certainly needs more phosphoric acid.

No. 10 is very similar, but not so good a soil. It has been much longer under tea. Organic matter is rather low for the type of soil, and added nitrogen will certainly give better crops.

No. 11 would be decidedly heavy and sticky were it not for its content of organic matter. It is practically a virgin soil on which the young tea is now splendid, though it at first hung fire when the drainage was deficient. The nitrogen is distinctly low; at present in the virgin soil what is present is in a very available state, but additions of nitrogen will soon be required.

A soil with so much clay and of so high an acidity must benefit from lime. So, probably, would Nos. 8, 9 and 10, but experiments should first be tried.

All these are heavy enough to need really good drainage. No. 12 is a medium soil, not because it contains both clay and sand but because it consists of the medium-sized particles only. This is the very finest physical type for a tea soil. Having little coarse sand, water movements are not too rapid, and having little clay they are never too slow. Hence it is a splendid soil in spite of its low content of organic matter. Chemically it is rich in minerals but rather low in nitrogen. Having neither clay nor high acidity lime is not likely to be required. These soils generally overlie coarse sand or gravel subsoils and blind drains leading the water into the pervious subsoil are generally sufficient, so long as these subsoils are occasionally tapped by deep drains, and the garden protected from outside water.

Similar to these Eastern Dooars soils are the characteristic soils of Mangaldai.

From their analyses the red bank soils, Nos. 13, 14 and 15, would be expected to behave as rather sticky clays in spite of their high sand content. These red soils, however, always behave as much lighter soils than the quantity of clay present would lead one to expect.

The clay particles measured by mechanical analysis are all those below ·002 mm. in diameter. In a red bank soil, however, the particles of clay size include a much smaller proportion of the very small sticky colloidal particles which give to true clay its peculiar properties.

All these are fine soils. No. 13 grows the oldest and worst, No. 14 the best tea on the same garden. Allowing for the fact that No. 14 is the lighter there is little to choose between the two soils. No. 13 carries distinctly poor tea for red bank soil. No. 14 gave 24 mds. per acre unpruned in 1915.

I believe that the difference is due only to the excellence of the plants and the way they were put into No. 14. This is only mentioned to show that the soil is not everything. The plant is of at least equal importance.

Although the red soils always do behave as lighter soils than would be expected, the average Dooars Red Bank soil does contain a very high percentage of fine particles, and is therefore largely dependent for its excellence on a high content of organic matter.

Note the high organic matter content of No. 15 which has not been long under tea.

There is every reason to suppose that most red bank soils approached these figures for organic matter when first put out, and it is my opinion that it is high time that strenuous measures should be taken to maintain and increase the organic matter content of the older soils.

The common practice of burning prunings year after year can only be deplored. If burnt at once, while green, something might be said for the practice as an anti-blight measure. Generally, however, purnings are left to dry before burning, by which time thay have done nearly all the damage they can.

It is a significant fact that the subsoils of some red bank soils are richer in organic matter than the surface soils. This can only indicate deterioration of the surface soil.

Decreasing organic matter may be one of the factors allowing increased damage from mosquito blight. Mosquito has been very serious of late years even on the fine tea of No. 14. No. 15 remains practically free. Note also the high available potash of No. 15.

Table I.

SANDY SOILS.

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
	Cachar Sandy Teelah.		Bishnauth Sand.	Jorehaut Soils.			Mal Sand (Dooars)
	Old	Virgin		Newer Deposit	Older Deposit	Silty type	
Soil Type.	2·1·5·4·3	2·1·5·4·3	1·2·3·5·4	2·1·3 4·5	2·3·4·5·1	3·2·5·4·1	1·2·4·3·5
Moisture as received	2·4	8·1	9·1	10·7	1·0	....	15
Hygroscopic moisture	2·1	0·5	0·7	0·4	0·8	0·9	1·4
Gravel and Stones	2·9	0·2	0 5	Nil	Nil	Nil	8·0
MECHANICAL ANALYSES.							
Matter soluble in dilute acid	0·9	0·4	0·2	·02	0·7	0·5	0·3
Coarse sand	31	32	56	22	5	2	64
Fine sand	34	36	·24	49	55	18	16
Silt	7	6	11	17	18	56	4
Fine silt	10	9	2	6	11	9	7
Clay	12	11	3	5	6	12	4
Loss on ignition	4·4	5·6	3·2	1·9	2·9	2·4	4·8
CHEMICAL ANALYSES.							
Grandeau organic matter	1·0	2·4	1·3	0·7	1·1	0·8	2·4
Acidity	1716	1190	922	245	1468	974	2633
Insoluble silicious matter	91	92	90	95	93	91	85
Nitrogen	·071	·155	·078	·064	·065	·067	·124
Total phosphoric acid	045	·034	·057	·068	·019	·034	·081
Available „ „	·011	·016	·011	·007	·001	·008	·019
Available potash	·020	·013	·005	·012	·013	·011	·009
Available lime	·012	·057	·038	·057	016	·021	·017
Available magnesia	·007	·040	·049	·015	·018	·018	·022

Table II.

MEDIUM SOILS LOOSELY TERMED LOAMS.

	8	9	10	11	12	13	14	15
	Sylhet Teelah.	Cachar Plateau.	Dibrugarh Medium Loam.	Central Dooars Clay-Loam.	Eastern Dooars Silt-Loam.	Red Bank Soil.		
Soil Type.	1·2·5·4·3	3·2·5·1·4	2·5·1·4·3	4·5·3 2·1	2·3·4·5·1	1·5·4·2·3	5·1·4·3·2	5·1·3·4·2
Moisture as received	15	21	15	17	20	17	18	27
Hygroscopic moisture	1·2	1·8	2·4	2·1	0·7	2·6	3·0	7·3
Gravel and stones	Nil	1·0	nil	1·4	0·2	1·4	1·8	4·3
Matter soluble in dilute acid	·4	·4	·2	2·5	·6	1·3	1·7	1·2
MECHANICAL ANALYSES.								
Coarse sand	39	15	16	10	5	25	19	22
Fine sand	23	26	34	12	31	14	10	6
Silt	8	25	12	13	29	11	12	17
Fine silt	11	12	15	32	25	18	18	14
Clay	14	16	17	21	6	23	33	31
Loss on ignition	4·7	6·4	5·9	8·8	3·5	7·1	7·8	9·8
CHEMICAL ANALYSES.								
Grandeau organic matter	1·9	2·1	1·8	4·0	1·4	2·1	2·8	4·3
Insoluble silicious matter	87	80	79	74	82	71	68	67
Acidity	1246	2264	1951	4464	853	2875	3671	3264
Nitrogen	·141	·125	·100	079	·089	·120	·118	·220
Total phosphoric acid	·037	·051	·087	·249	·157	·082	·152	·099
Available phosphoric acid	·011	·006	·015	·043	·060	·012	·014	·016
Total potash	.....	·393	.....	·73	.....	·85	·87	.....
Avaliable potash	·011	·011	·015	·024	·017	·016	·018	·024
Total lime	.....	·092	....	·130	.....	·131	·094	.....
Available lime	·027	0·31	·016	·033	·145	·054	·028	·030
Total magnesia	.....	·600	.....	·73	.....	1·45	1·09	.....
Available magnesia	·009	·050	·013	·065	·112	·050	·06	·033

Table III.

CLAY SOILS.

	All from Hailakandy District of Cachar.				Bheel Soils Cachar.	
	16	17	18	19	20	21
Average yield maunds with coarse plucking	....	6	14	30	Good peat bheel.	Deteriorating bheel.
Soil Type.	5·4·3·2·1	4·5·3·2·1	5·4·2·3·2	4·5·3·2·1		
Moisture as received	29	26	24	19	62	10
Hygroscopic moisture	·5	2·0	10·9	3·1	10·4	2·7
Gravel and Stones	Nil	Nil	nil	Nil	Nil	Nil
MECHANICAL ANALYSES.						
Matter soluble in dilute acid	·48	·71	1·97	2·36	2·5	1·2
Coarse sand	Nil	0·3	·02	0·4	Nil	35
Find sand	2	9	17	4	7·0	33
Silt	7	18	16	10	7	8
Fine silt	41	35	27	39	26	10
Clay	43	29	28	31	11	3
Loss on ignition	5·6	6·4	8·4	12·6	33	7·3
CHEMICAL ANALYSES.						
Grandeau organic matter	2·8	0·8	3·7	4·7	20·4	3·3
Acidity	2381	1733	3215	2984	5251	1841
Insoluble silicious matter.....	73	79	75	74	55	87
Nitrogen	·236	·116	·200	·213	·574	·123
Total phosphoric acid	·088	·026	·068	·114	·194	·065
Available ,, ,,	·022	·014	·005	·025	·053	·014
Total potash	.....	·23	.....	·64	.....	.....
Available potash	·010	·011	·014	·013	·036	·025
Total lime	.....	·19	.....	·94	.....	.....
Available lime	·057	·094	·083	·127	·024	·022
Total magnesia	.....	·28	.....	·23	.....	.....
Available magnesia	·057	·079	·041	·026	·030	·010

A FEW NOTES ON DISEASE TREATMENT

BY

A. C. TUNSTALL, B.SC.

There are a number of diseases of tea, *e.g.*, Grey blight, Brown blight, commonly present, which only do serious damage under exceptional circumstances. As a rule, the treatment of these diseases does not pay. Some leaf and stem diseases and all root diseases are dangerous, and, if unchecked, may cause great loss. To send specimens to Tocklai takes time. Time is often of the utmost importance and treatment should be put in hand at once. At the same time, specimens should always be sent to Tocklai for identification and the treatment may be modified later in accordance with special recommendations based on the nature of the particular disease. Most of the points raised in this article have been frequently emphasised in our publications, but the writer has endeavoured to put them together as concisely as possible so that the planter may get on with the job without the delay necessitated by hunting for mislaid copies of earlier publications.

PARASITIC FUNGI IN RELATION TO THE TEA PLANT.

Some fungi live outside the plant and thus can be killed by fungicides at any time, but most of the fungi causing tea diseases live mostly within the plant. Fungicides cannot reach such fungi at all times. It is, however, possible to kill the spores when they are formed on the surface of the plants and to protect the plant from infection by the spores by coating it with fungicide. If the life history of the fungus is known, the times of spraying may be arranged so that the plant is protected while the spores are being produced and the spores may be killed at the same time. In the tea districts the rain soon washes off the fungicide, and moreover the new leaf is continually forming on a plucked bush. It is necessary therefore to repeat the spraying at intervals. For instance,

in the case of Blister blight the first spraying will kill the spores actually present when the application is made and protect the foliage for a few days from attack. It will not kill the fungus which is developing inside the leaves. As from our knowledge of the life history of the fungus we know that it takes 10—11 days after infection to produce its fruits. It is necessary to keep the bush protected for that period, as the fungus in leaves infected just before the spraying would take 10—11 days to develop. As the spray fluid is washed off or the new leaves appear within a week, the spray fluid should be applied again about a week later.

Where the fungus is common in jungle round the tea it is obviously impossible to protect the plants from infection adequately by spraying, and other methods have to be found.

The Plant Reacts to Stimuli Caused by Mechanical Injury or Plant Disease.

When a plant is injured in any way, it sets to work to repair the injury. When a fungus is the cause of the injury, the plant reacts to stimulus produced by the fungus. Different fungi cause different reactions. Some cause the diseased portions of the plant to grow more rapidly, thus causing cankers, etc. Others kill the diseased tissues very rapidly and feed on the dead substance. By studying the action of the fungi on the tissues it is sometimes possible to devise means of killing the fungus, even though it is inside the plant, *e.g.*, the fungus causing Thyridaria tarda is frequently destroyed by the plant itself when conditions are favourable.

The tea plant in a normal condition is able to resist the attacks of many of the fungi which cause its disease, but when the vigour of the plant is lowered those fungi cause disease and make matters worse.

Manurial Treatment.

If a soil is deficient in any necessary constituent, the plants growing thereon are less vigorous and, in consequence, more susceptible to certain diseases. It has been found that deficiency in potash often predisposes plants to disease infection. Manuring with potassium nitrate or a mixture containing potash and nitrogen

in a readily available form will often check attacks of Brown blight, Red rust and Thyridaria tarda. The application of such a manure is only useful when the soil is moist and the plant is actively growing.

How Fungi are Distributed.

Fungus spores are usually very small indeed, and, in consequence, can be carried long distances by wind. Some spores have special arrangements to facilitate this, *e.g.*, filaments of Grey blight. Other spores have a sticky coat, *e.g.*, Brown blight, so that they stick to insects, etc., and are thus carried about. Some fungi which rarely produce spores, *e.g.*, Thread blight, are distributed by the dispersal of dead leaves, etc., bearing portions of the fungus mycelium thereon. Diseased tea bushes like diseased animals should be isolated as far as practicable. Whenever a large area of one kind of plant is found there is danger of epidemic disease. Some of the diseases of tea are always present, yet under ordinary circumstances do little damage, but there is always the possibility of their becoming serious under special conditions. There is a still greater possibility of new diseases appearing in epidemic form, and whenever a new disease is noticed no effort should be spared to eradicate it before it becomes general. The enormous damage which an epidemic of disease may cause should never be lost sight of and a constant watch should be kept for anything new.

What to do When an Outbreak of Serious Disease is Discovered.

Always send specimens of any unrecognised disease to Tocklai at once, with full particulars of soil, jat of tea, age of tea, weather conditions during the development of the disease, extent of damage, and any other relevant details. The disease may be doing little damage, but under other conditions it may become serious. If the specimen is sent to Tocklai, the department is able to investigate the disease and to be in a position to suggest remedies, should the disease at any time become serious.

In the Case of Stem or Leaf Diseases.

1. Isolate the bushes concerned by preventing coolies, cattle, etc., from touching them. All the necessary cultivation, etc., should be carried out by special coolies, using specially marked implements. At the conclusion of the operations for the day the coolies and implements should be sprayed with lime-sulphur solution on the spot so that the disease will not be carried about.

The lime-sulphur solution does not injure the skin or clothing, but should not be allowed to get into the eyes. The solution is also a cure for itch and various other skin diseases.

2. Pluck or prune off all the diseased portions and burn them on the spot. If they are too green to burn alone, a little kerosine will help matters.

3. Spray the bushes thoroughly with a fungicide, *e.g.*, lime sulphur.

Repeat the plucking, pruning and spraying at intervals, depending on the nature of the disease.

Where there are numerous outbreaks occurring at the same time, treat the small ones first, isolating the larger areas until time permits treatment to be carried out on them.

In the Case of Root Diseases.

1. The areas containing the dead or dying bushes should be isolated and all the implements used in cultivation, etc., of such areas should be kept separate. There is no need to disinfect the coolies.

2. The edges of the large areas and all small areas should be dealt with first by digging out the dead and diseased bushes, taking great care to remove all the dead wood from the soil.

3. All the dead wood should be burned on the spot if possible. If it is not feasible, it should be removed in old bags or baskets and burned elsewhere. Care should be taken to either burn the bags or baskets or disinfect them thoroughly with lime-sulphur solution.

4. Watch for new outbreaks and deal with them at once.

5. Dig out all dead wood and heavily lime the soil some months before replanting.

In planting out, be very careful to clear out all the dead stumps. This operation is costly, but very desirable. Jacks are very useful for removing smaller trees, and the large stumps may be used as centres of the burning of piles of wood collected round them.

Spray Fluids.

For use in the rains *lime-sulphur* solution is the most satisfactory.

This solution is best prepared according to the following formula :—

Quicklime	...	... 20 lbs.
Sulphur	...	... 22½ lbs.
Water	...	... 50 gallons.

The lime should be put into a drum holding 50 gallons and slaked by adding water gradually. When it is fully slaked, add about 30 gallons of water and bring to the boil. When it is boiling add the sulphur gradually, stirring vigorously during the whole time, and when all the sulphur has been added pour in boiling water to the 50 gallons' mark. Boil for an hour longer, keeping the volume at 50 gallons by adding boiling water. This gives the stock solution, which, when cool, may be diluted with 10 or 12 volumes of water and used immediately.

Great care must be used in its preparation, and if it be desired to keep the stock solution, it must be stored in full, air-tight vessels, or, if the vessel is not full, with a layer of oil on the surface.

Lime-sulphur solution should not be stored in copper vessels, or sprayed on to bushes from copper spraying machines. Great care must be taken to see that all spraying machines are thoroughly cleaned out after use.

The sediment need not be thrown away, but may be boiled up with about 10 gallons of fresh water. The resulting liquid should be tested, when cool, with a hydrometer and diluted according to the table given in the spraying pamphlet. The water used for diluting the stock solution may be mixed with fresh cattle manure and carefully strained. This makes the fluid stick on better and renders it visible on the leaves.

This solution is very useful for the treatment of itch and ringworm on coolies.

For use in the cold weather *Burgundy mixture* is recommended, because it sticks on to the bushes for a long time.

To make 50 gallons 1% Burgundy mixture

Dissolve 5 lbs. of crystallised copper sulphate by suspending it in a piece of sacking in two and half gallons of warm water (if required immediately). If cold water is used, the copper sulphate may be left to dissolve overnight. In the same way dissolve 2·3 lbs. of soda ash.

Add the soda ash solution gradually to the copper sulphate solution, stirring all the time, until the mixture becomes neutral. This can be tested with litmus paper. The solution should be either neutral or very slightly alkaline, but never acid. The mixture will not be affected to any great extent by standing for a short time in iron vessels, but the copper sulphate solution will be. It is therefore necessary to dissolve this substance in wooden, copper or earthen vessels. The soda ash attacks iron a little but not sufficiently to make any serious change in the solution.

The addition of the above mixtures will make 5 gallons concentrated mixture which, when diluted to 50 gallons, will be 1% Burgundy mixture.

(Litmus paper is made up into little books of narrow strips. It is either blue or red. The red colour may be changed to blue by alkalis, and *vice versâ* by acids. Neutral solutions do not affect the colour of the paper.)

The Hydrometer.

The use of a hydrometer in testing the strength of solutions, such as copper sulphate, carbonate of soda or lime sulphur, is recommended. There are tables for this purpose in the spraying pamphlet. The solution must be cold when tested. By using the hydrometer it is possible to check the accuracy with which the solutions are being prepared.

A paint for use on pruning cuts may be prepared by dissolving 5 lbs. of copper sulphate in 10 gallons of water and making it up to the consistency of paint by adding slaked lime. The use of rice water instead of ordinary water is recommended, as it makes the paint stick better.

A suitable brush for painting cuts and applying caustic soda solutions is made as follows :—

Take a piece of bamboo, about $1\frac{1}{2}$ inches in diameter and 2 feet long, having a knot at each end. Bore out the knots with an auger. Take a piece of tow of sufficient size, tie a piece of wire round the middle, leaving an end long enough to go the length of the bamboo and project at the one end. Thread the wire through the bamboo and pull the tow into position at the end. Fix the loose end by means of a wooden plug driven into the hole.

Spraying Machines.

The most useful ones are of the preasure type with internal pump. *Nozzles* should be the simplest obtainable—containing no springs or joints. A four-nozzle attachment has been found very useful for spraying large areas.

Don't use expensive spraying machinery for corrosive fluids, such as caustic soda. Use cheaply made brushes for such fluids.

Always have machines washed out thoroughly at the end of each day's work. When some solutions become concentrated by the evaporation of the water, they become able to attack the metal of the machines. The washing of the machines prevents this.

Dusting.

Dusting with sulphur mixed with fine silt or clay in the proportions of 1 of sulphur to 9 of the powder is recommended for protecting the bushes on the sides of roads and paths leading from infected areas. The dust should be extremely fine and should be distributed by a machine.

Always have spraying machines and materials ready for immediate use. This precaution may save a fortune some day.

Remember time means money, and neglect of a small outbreak may mean great loss.

METEOROLOGICAL OBSERVATIONS IN ASSAM, 1922

BY

C. R. HARLER, B.SC., A.I.C.

INTRODUCTION.

In 1920 the Agricultural Research Council in England appointed a Committee to consider the data supplied by the Meteorological Office and to make suggestions for the fuller use of such information. The Committee's report is full of interest to agriculturists and contains many suggestions which are being acted upon at Tocklai.

There are three ways in which a Meteorological Office assists agriculture, first by providing information as to prevailing or recently prevailing weather, secondly by issuing forecasts of the weather to be expected, and thirdly by research (7).

Obviously no weather forecasts can be made from Tocklai, for this necessitates a knowledge of meteorological conditions over a great area. So far our work has been one of recording and research.

There is an obvious connection between plant pathology and weather conditions. Thus Potato Blight is associated with wet, mildews with dry summers. With tea, we associate Brown Blight with hot, scorching sun, Red Spider with a bad growing period particularly drought, and Blister Blight with cold winds, under certain conditions, blowing from the hills. It is only by keeping a detailed account of the weather parallel with observations on pests and blights that the extent of the relationship between the two can be seen.

The influence of the atmospheric humidity on both tea growth and tea manufacture is of fundamental importance and is discussed in some detail later on.

The optimum temperature for tea growth has not yet been settled, neither has the most suitable rainfall. The former factor must vary considerably with other conditions and the latter is no doubt dependent largely on the type of soil and subsoil.

It is only by continuous and detailed observations that anything approaching a true correlation between the weather and the growth and condition of the tea plant can be made. When this has been done, the falling off in crop in any area will be more easy to explain than at present and at the same time the treatment of such an area will be simplified.

The observations made below are in continuation of those made in a previous Meteorological Report (4).

The Monsoon in Assam during 1922.

The monsoon in Assam differs considerably from that experienced generally in Northern India. In provinces other than Assam, the drought as a rule continues till about the middle of June and the rains ceases towards the end of September. The rain corresponds with the moving north of the thermal equator and the steady uptake of air from the Central Asiatic plateau enormously accentuates the inflow of rain bearing winds to North India.

In most parts of North India three definite seasons, cold, hot and wet, are distinguished, but in Assam there are roughly two, the cold, dry season and the wet, warm one.

In Bengal the year is divided by the Indians into six seasons. *Basanta* is the Spring season and corresponds roughly to February and March. *Grisma* is the hot or summer season and corresponds to April and May. These two seasons coincide with what is termed the hot weather. *Barsa* and *Sarat* are the rainy season, and the end of the rains corresponding to June, July and August, September. *Hemanta* is the beginning of winter, the dewy season, and

Seath is winter. These seasons fall in October, November and December, January respectively.

The Assamese have similar names which are adapted to the modified climate.

The climate of the Assam valley is dominated by the Tibetan plateau to the North and by the Patkoi range which forms the Southern boundary of the valley. Often, well on into May, cool breezes flow from the Himalayas into the valley. Before the break of the true Monsoon, rainfall is generally accompanied by a rise in temperature which denotes that the rain-bringing wind originated in the South. Rain clouds which once get into the valley usually circulate round the hills till they are dispersed, so that it often happens that the rain appears to come from the North.

During the period March, April, May, the weather is changeable and is usually alternately hot and cool with a general tendency to get hotter.

In June the uptake of air from the Tibetan plateau becomes steady and the Monsoon advances so that up the Assam valley a steady south-west wind blows and the sky is cloudy and overcast for two months. In August and September there is a period of comparative equilibrium and clear and cloudy skies alternate. Early in August it is frequently observed that the breeze blows direct from the North.

October sees the Monsoon definitely in retreat and the wind blows steadily from the North.

In the year under consideration only 73·89 inches of rain fell. This figure is 6·62 inches below the average but is quite sufficient to ensure a good tea crop if the distribution is good.

As was mentioned in a previous report (4) a first approximation to the degree of wetness may be obtained by dividing the product of the monthly rainfall and the number of wet days by the number of days in the month.

In the table is given the rainfall and the distribution at Tocklai for the past five years.

Table showing Monthly Rainfall and Degree of Wetness at Tocklai.

Months.	Rainfall in inches					Degree of wetness.				
	1918.	1919.	1920.	1921.	1922.	1918.	1919.	1920	1921.	1922.
January	0 12	0·28	0·63	1·63	0·74	0·004	0 02	0·04	0·42	1·58
February	1·26	0·97	2·73	0·86	0·12	0 18	0·17	0·87	0 21	0·01
March	6·37	0·75	6·15	4·21	3·14	3·29	0 07	2·97	1·22	0·81
April	5·91	7·41	9·08	14·03	7·79	2·16	1·91	3·60	10·29	3·11
May	15 42	6·57	6·73	9·28	6·16	6·96	2·54	2 38	5 08	3·17
June	14·92	22·09	9·89	7·71	11·67	8·61	12·51	6·59	6·42	10·11
July	18·20	16·37	14·18	14·52	12·87	11·77	10·56	8 46	9·84	10·37
August	19·48	10·71	9 22	9·71	19 23	11·31	4·42	5 94	6·57	16·12
September	12·44	9·59	6·17	14·23	7·32	6·22	5·75	3·08	9·49	3 90
October	2·42	9·40	2·47	5·15	2·65	0·31	3·33	0·72	2·66	0·59
November	0·40	0·40	0·40	nil	1·17	0·13	0·56	0·26		0·16
December	nil	0·01	0·13	1·14	1·03	...	0·01	0·01	0·11	0·16
Total	96·94	75·08	67·55	28·47	73·89	...	..	..	...	...

In order that the degree of wetness values for each month shall be directly comparable they must be combined with other factors, not the least important of which is temperature. For, a degree of wetness of 3 in October, when evaporation is decreasing owing to falling temperatures, will mean much more than a similar figure in September.

It is interesting to note that August 1919 was a bad period for tea growth, although the rainfall compared favourably with 1920 and 1921. But most of the 10·71 inches which fell in this month was precipitated in five days. This is shown in the degree of wetness which is considerably below that of the same month in 1920 and 1921.

The beginnings of 1918 and 1920 were the best early seasons for some years past and 1919 is remembered as being a stand out season with regard to the end, although the early part of the season was bad. It will be noticed that all three instances occur at periods of rainfall above the average.

On the chart the weekly rainfall is shown by means of black vertical lines.

So far as rainfall is concerned, there are two critical periods in the season. The first is in March, April and May, and the other in September and October. The rain seldom fails in the months between, but is usually in great excess.

In 1922 the start of the season was particularly bad, for the drought continued, with only one break, till the end of April. On this account transplanting was held up and infillings often failed. Unpruned tea suffered much on account of the amount of leaf it was carrying. Pruned tea did not produce much leaf till the rain came, and it then went steadily ahead of the unpruned.

The end of the season was also one of drought. September was a dry month and, but for two falls early in the month, there was no precipitation in October. Previous to this, much of the leeway following on the early rain shortage had been made up by means of excessively heavy falls doing more harm than good. With good late rains a crop well up to the average might have been expected.

The cause of this shortage of rain at the end of the season was apparently due to a barometric depression in the United Provinces and the Punjab. This deflected the general air movement from Assam, and when the depression had disappeared the wind swung round to the North and the chance of late rain diminished.

This is a case when meteorological observations over an extended area might have enabled an early prediction of the close of the tea season, with much advantage to the tea industry.

The rain which usually falls about Chrismas time is probably the result of the barometric depression which passes from Europe across Persia and into India.

Temperature and Humidity.

Observations in connection with many plants show that the dominating factor in plant growth is temperature. Below 42°F plant growth ceases and at present we use accumulated temperature above 42° as an index of favourable condition for plant growth. As the temperature increases so the rate of growth increases, till the thermic optimum is reached and then growth decreases. At the same time, this optimum varies with the duration of exposure of the plant. The longer the duration of the exposure, the lower is the optimum. Between the optimum and the vital temperature, *i. e.*, 42°, the rate of growth is doubled for every 18°F rise in temperature (6).

Now these factors are of the utmost importance in the study of the growth of tea. We do not yet know the exact optimum temperature for tea growth, but it is believed to be about 90°. As shown above, this optimum will be lower when the time of exposure is longer and higher when the time of exposure shortens. Now August is often a month of depression so far as tea crop is concerned, although, on the average, the maximum temperature is slightly less than that of June and July. This depression may be partly due to soil condition, but it may also be due to longer exposure in August and September, which results from skies less cloudy than in previous months with an advancing monsoon.

The year 1922 was remarkable for the steady temperatures during the monsoon period and shows a marked contrast to the previous season.

On the chart the average weekly maximum and minimum temperature are denoted by red lines. In the rains the difference between the two temperatures is about 10°F., whereas at other times it increases to 20°. This has an important influence on the vapour tension of the atmosphere.

Closely correlated with temperature and with rainfall is the humidity of the atmosphere. That humidity has a tremendous influence on the tea crop is undoubted, but only after many more observations can we say which type of observations—relative or absolute humidity, dew point or readings of the wet bulb thermometer—will be of most use to the tea industry. In any case, wet and dry bulb thermometer readings, from which humidity and dew point are calculated, should be made daily.

Here a brief account of the theory of the wet and dry bulb thermometer may be given. A more detailed account, together with general instructions to Meteorological Observers in India, is given in an Indian Government publication (3).

A common method of cooling water and air in India is by means of evaporation. Thus wet cloths hung round a fermenting room cool the air which passes through, becauses the moisture in the cloth evaporates and, in doing so, takes heat from the air. The quicker

the cloth dries the cooler becomes the air passing through it. Similarly earthenware vessels containing water keep cool by virtue of the thin film of water which soaks through to the outside of the vessel and evaporates.

The same thing happens with a wet bulb thermometer, which is simply an ordinary thermometer surrounded by a piece of muslin attached to a wick saturated with water. The wet bulb will be cooled because the muslin dries. The quicker this drying takes place the more the thermometer will be cooled and the greater will be the difference between the wet and the ordinary (dry bulb) thermometers.

During the misty mornings which occur in the cold weather there will be no difference between the wet and dry bulb thermometers, for no evaporation is possible. On a hot, dry day such as often occurs in May the difference will be great. Here, then, is a measure of the humidity of the atmosphere, for the greater the difference between the two thermometers, the dryer the atmosphere.

It is further necessary to distinguish between *relative* and *absolute* humidity. In the cold weather when a mist is lying about, the atmosphere is saturated and the relative humidity is 100. If the temperature were suddenly raised about 10°F., the mist would clear and the relative humidity would fall, as it often does, to about 70, although there is still the same amount of moisture in the atmosphere as there was when the air was cooler, *i.e.*, the absolute humidity is unchanged.

During the nights in the rains the atmosphere is generally saturated and the relative humidity is then 100, but the actual amount of moisture in the air is often three times the amount present in the cold weather when the atmosphere is saturated. This difference is not measured by the relative humidity, which is merely the amount of moisture in the air compared with that necessary to saturate the air at the same temperature. This latter quantity varies with temperature so that the same amount of moisture may correspond to any number of relative humidities.

The relative humidity varies greatly throughout the day and may alter from 100 at 10 A.M. to 50 at noon when the mist

clears. This is especially the case in the cold weather. The absolute humidity seldom shows such sudden variation, although it shows a steady change over periods of days.

The average weekly absolute humidity or vapour tension taken at Tocklai at 10 A.M. daily is shown by a blue line on the chart and is registered as inches of mercury. Thus, when the vapour tension is 1·10 it signifies that out of a barometric pressure equivalent to the weight of about 30 inches of mercury, 1·10 inches are due to water vapour.

Both the relative humidity and vapour tension (absolute humidity) are calculated very simply from wet and dry bulb readings by the aid of tables found in many meteorological books (1).

It will be understood that before the absolute humidity of the air can be appreciably increased there must be a hot period extending over several days and, at the same time, the nights must not be cold enough to precipitate as dew all the extra moisture taken up. It usually happens that right to the end of May, although the daily temperature rises to 90°, the absolute humidity does not greatly increase because the night temperatures fall to about 70°. In the monsoon no such fall occurs at night.

The question of humidity (humidity of air irrespective of rainfall) has an important bearing on the growth and manufacture of our tea as well as on insect and fungus attack.

So far as the growth of tea is concerned it appears that the crop follows more or less the vapour tension curve.

Brief mention was made of the mechanism of transpiration and its relation to atmospheric humidity in last year's report. When the air is moist the transpiration of the leaf is hampered and the bush must grow more leaf in order to be able to get rid of its excess moisture. It usually happens that excessive humidity goes with high temperatures, so that here the bush is reacting to two factors which are inter-related.

In 1921 the form of the crop and vapour tension curves showed a remarkable resemblance, and one was tempted to conclude

that there was a high degree of correlation between the two. In 1922, however, it is seen that there is not a close resemblance. If naturally there is a close correlation, then it must be concluded that the treatment of bushes in 1922 (*e.g.*, method of plucking) has not been such as to allow this relationship to be in evidence.

When the leaf is plucked and withering begins, the vital forces in the leaf diminish and the drying takes place more and more on physical lines. Wilting gives place to withering. In this case the influence of the absolute humidity decreases and that of relative humidity increases. In the damp nights experienced during the rains a good wither is impossible under ordinary conditions. It may be said that rapid growing weather is bad manufacturing weather.

This statement may be illustrated as follows :—

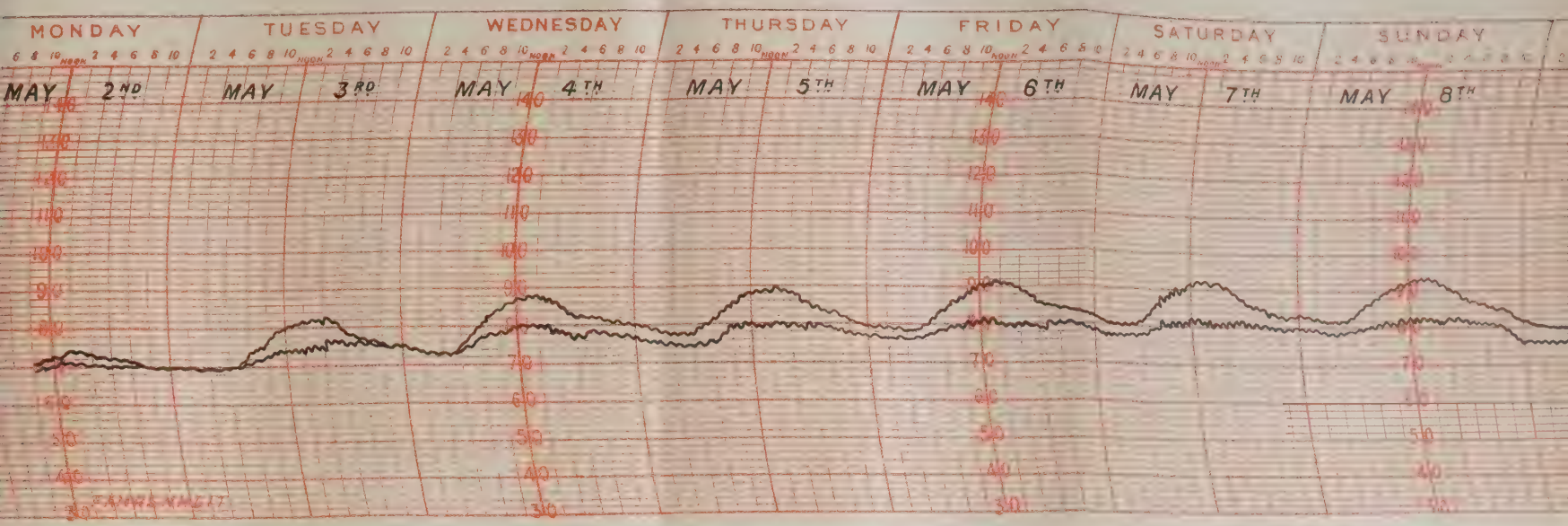
Opposite on charts I to IV are shown four graphs taken from the hygrograph. The hygrograph is an instrument which mechanically measures the wet and dry bulb readings throughout the day. The upper line represents the dry bulb reading, or the ordinary air temperature, and the lower line, the wet bulb reading. When the two lines come together it signifies that no evaporation is going on from the wet bulb, *i.e.*, the air is saturated. The further apart the two lines are, the dryer is the air and the less the relative humidity.

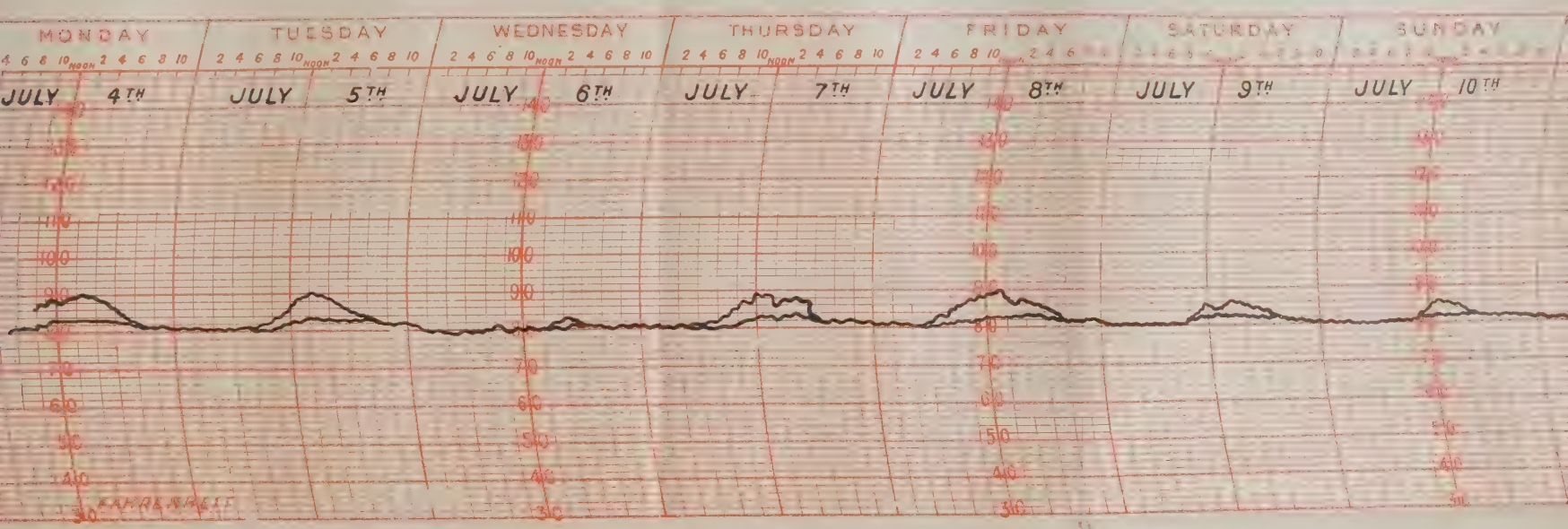
The first chart is for the week ending May 8th, 1921. This is a dry week with a steadily rising temperature and typical of what may be expected at this period. The nights are warm—the temperature scarcely falling below 80°—and the vapour pressure is rapidly mounting. The bushes are flushing well, but it is too dry for a good wither unless the side curtains of the withering house are lowered to reduce wind effect.

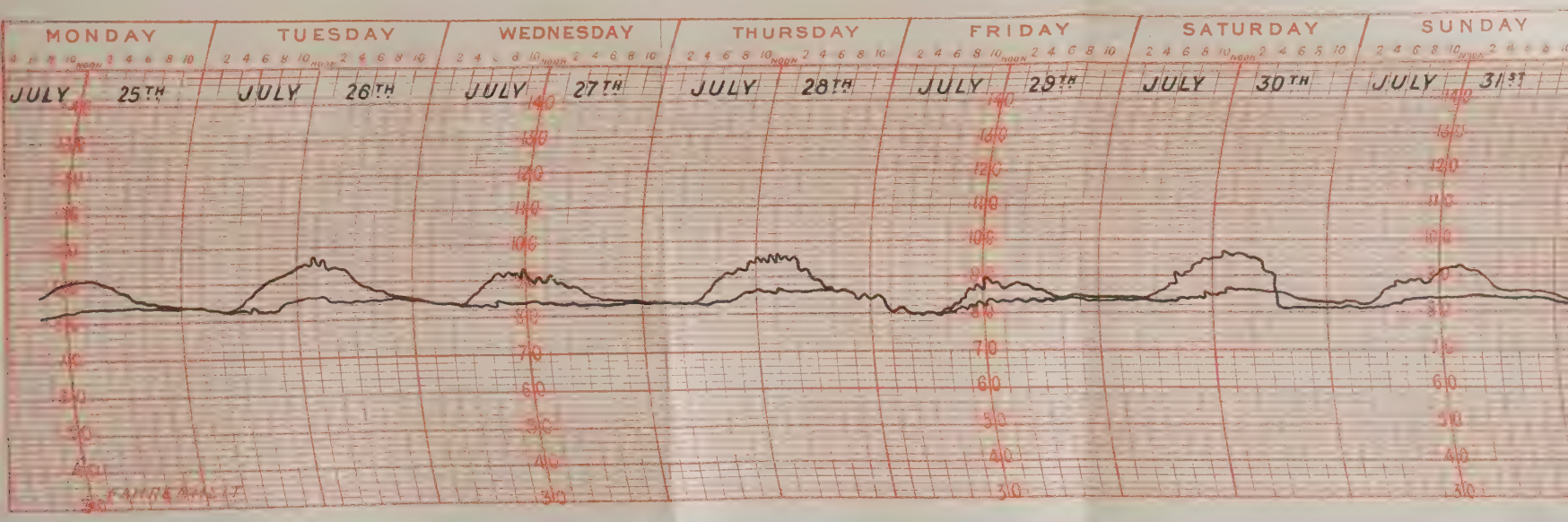
The second chart represents conditions two months later when the Monsoon is fully advancing. There is copious rainfall and the irregularities in the dry bulb reading during the day represent showers and cloudy intervals. In such dull, steamy weather, crop is plentiful but a good wither impossible.

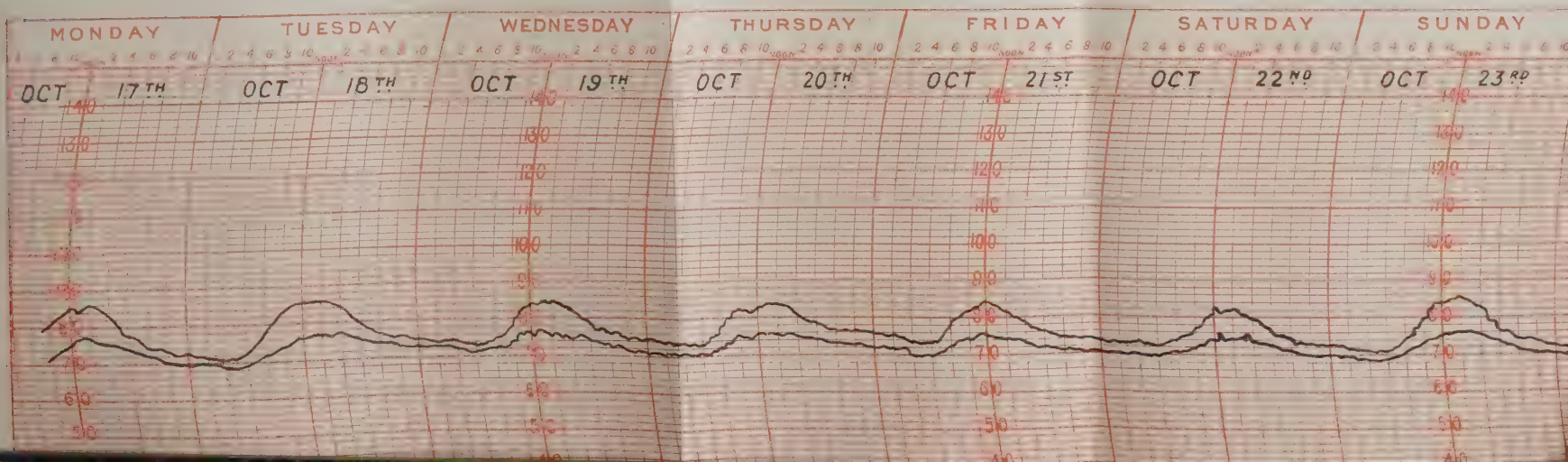
HYGROGRAPH CHARTS

RECORDED AT TOCKLAI EXPERIMENTAL STATION DURING 1921.









The third chart is for the week ending July 31st, a fortnight later than the previous chart. The atmosphere is still saturated at night, but the night temperature is generally higher than during the week ending July 10th and the atmosphere by day is comparatively dry. A fair wither would be obtained. Good growth should also be obtained at this period, but as a matter of fact a spell of *banjhi*-ness had come over the bushes. This may have been the result of excessive leaf production earlier on.

The fourth chart is for the week ending October 14th. The form of this chart is similar to that of the week ending May 8th, but the temperature is about 10°F. lower. The bush at this period is not growing fast owing to the low temperature. A good wither is obtainable.

When the exact and separate significance of temperature and humidity in connection with the withering of leaf has been determined, great advances can be made in tea manufacture.

The length of the fermentation time must vary with the weather which, in turn, varies every day and throughout the day. Usually in September the time necessary for fermentation must be increased. It is common for the time to be increased from $3\frac{1}{2}$ hours in the rains to 5 hours in October.

Now the necessary increase in the time of fermentation is on the whole a steady one, but there are days when the time must be put back and days when it must be put forward a greater amount than usual. The planter of experience knows by the feel and the colour of the leaf when it should be ready for firing. With such a man tea making is an art, and it can only become a science when, by careful and detailed climatic observations, we can state definitely how long the fermentation process should be under any special set of conditions.

Sunshine.

At Tocklai the hours of bright sunshine are measured daily. The apparatus is a simple one and consist essentially of a closed cylinder in which is an aperture. Inside the cylinder is sensitized paper. As the sun traverses its path the spot of light

projected from the fixed aperture moves accross the piece of photographic paper divided according to hours, leaving a dark line.

The average daily sunshine is considerably less during the monsoon than at other times. The weekly average shows considerable variation and is roughly an inverse measure of the rainfall. Sunshine is the complement to rainfall. Long sunny days denote high temperatures and good growth, which is different from the forcing growth shown in dull weather when the shoot contains large sappy leaves and a big percentage of stalk.

It has been shown (5) that shade reduces the tannin content of the leaf, although the loss of quality in this direction is more or less counterbalanced by increased crop.

During the season 1921, teas on the whole were poor in liquors and pungency, in spite of the finer plucking resorted to in that year. A possible explanation of this is that the sunshine in this year was below the general average.

Another factor which would make for poor teas in 1921 was long, as opposed to close, plucking.

The table below shows the monthly sunshine average in hours over the past five years, recorded at Tocklai.

TABLE.

Year.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1918	6·95	6·14	4·23	5·76	5·10	3·31	3·71	3·74	5·00	6·22	6·27	6·51
1919	5·27	6·10	6·91	6·06	5 69	5·05	3·57	5·26	3·35	5·06	5·24	4·96
1920	4·60	3·96	4·39	4·61	4 32	3·89	5·22	5·08	5·62	4·90	6·07	5·03
1921	5·03	5·45	5·22	3·89	3·91	3·11	3·71	3·93	3·49	2·58	5·51	4·48
1922	5 30	7·42	4·50	6·07	6·03	4·11	4·52	3·50	4·55	6·10	5·91	6· 3

We may correlate fairly closely some of the pests and blights of tea with sunshine. Thus Brown Blight usually follows a hot, scorching sun. Red Spider on a waterlogged soil is dispelled by a sunny period, although the connection is not so close as might be expected. Any change in the weather which causes fresh growth overcomes Red Spider. Blister Blight disappears with the advent of a spell of sunshine, chiefly because the temperature rises.

The Soil Condition.

Throughout the year daily soil samples were taken from the top 9″ of the Tocklai Clearance. The soil here is a sandy silt with an optimum water content of about 14%. The average weekly moisture throughout the year is shown on the top line of the chart and the arrows denote cultivation. The moisture ranges from 10 to 20%.

During the first three months of the year the soil steadily dried out and at the end of March it was powdering badly and in a condition impossible for cultivation. At the beginning of April the drought ended, but there was not sufficient precipitation to greatly influence the subsoil nor to raise the water table to within a distance which would enable the upper soil to draw on it for moisture. The result was that in the middle of April, drought was again in evidence and the soil moisture fell sharply to 10%. With the coming rain again the moisture increased and, to about the end of May, it was almost at the optimum. In June it rose to about 19% and remained at about that figure till the rains began to tail off. It will be observed that on one occasion only did the moisture go beyond 20%.

For about three months in the middle of the rains no cultivation was done, but the jungle was kept down by sickling. The question of rains cultivation has been discussed elsewhere (2), but a remark may be made here on the September hoe. Now cultivation is apt to be a wasteful process. By cultivation soil food, especially nitrates, is made available, but when a heavy shower falls this food is washed away. This has been observed at Borbhetta in connection with nitrate accumulation. The ideal time to cultivate is a day or two after rain with a week or so of dry weather ahead. In this case the soil will not be so wet that a great amount of tilth is destroyed. This is a case where it pays to be weatherwise.

At Tocklai the soil, being a light one, is not liable to serious loss of tilth from rains cultivation, but from the aggregates of clay particles which are broken down, particles may be washed through the soil and there will be a tendency to pan formation, with the deep hoe, however, these particles should be brought to the surface again.

The soil temperature at 1 foot and 3 feet depths was taken twice daily, at 10 A.M. and 4 P.M. from May till the end of the year, at Tocklai. The soil in which the temperatures was taken is sandy, well drained and under grass.

Not enough figures are yet at hand to draw any conclusions nor to interpret any results. To the end of August the difference between temperature at 10 *a.m.* and 4 *p.m.* is about 3° F. on a clear day. In May or June the maximum temperature is reached at about 5 P.M. From September onwards the temperature at 1 foot follows the maximum air temperature.

At 3 feet the diurnal variation in temperature is practically nil. From May to July in the year under consideration it rose steadily from 80° to 89°, at which approximate temperature it stayed till September when it feel steadily to 75° in December. From September onwards the soil was warmer by 2° or 3° at 3 feet than at 1 foot.

During the hot weather it was observed that any great change in the temperature of the top foot is followed by a similar but smaller change at 3 feet about 30 hours later.

The Tea Crop in 1922.

For purposes of correlation of crop with meteorological observations the leaf from the Tocklai Clearance was taken. This is an area of 3½ acres consisting of half acre blocks of Burma, Kalline, China, Kharikatia, Singlo, Betjan and Panighat tea. During the year under consideration half of each block has been skiffed and the other half cut to 16″, *i.e.* 2″ new wood on the last year's pruning.

The total crop curve is shown by a black line on the chart. The form of the curve is quite different from that of last year (4) when five distinct flushes were noticeable. In 1921 the pruning was different, the tea which was skiffed in 1922 was cut to 10″ and the tea cut to 16″, in 1921 was cut to 14″.

The plucking at Tocklai is seven days and to the *jhanam* from the beginning of the season. This is very hard, and since

the plucking area was kept absolutely level there was a tendency to remove immature leaf. On this account the flushes were obliterated and a fairly level crop obtained throughout the year.

The most striking point in the crop curve is the depression in June, which appears to be the aftermath of the drought. The leaf at this period was all very small.

The season closed more rapidly than usual, and after the middle of September the crop fell off as suddenly as it had come on in the early part of the season.

The two red lines under the crop curve on the chart refer to the unpruned and medium pruned yields which go to make up the total crop denoted by the black curve. The continuous line represents the unpruned and the broken line the medium pruned tea. Few remarks are necessary. It is easily seen that 1922 was a season which, by reason of the early drought, was all against unpruned tea, carrying as it does a lot of leaf. By the time the medium pruned tea was carrying its full complement of leaf, the drought had broken.

It will be noticed that at the end of the crop curve a break is denoted. On account of the falling off in the crop, a ten-day pluck had to be made.

In conclusion, mention may be made of the value of keen and detailed observation in all agricultural practices. To be successful in agriculture the power of observation must be highly developed. But isolated observations are of little use and it is only when two phenomena are correlated that scientific advancement can be made.

Every stage in tea growth and manufacture is profoundly influenced by the weather. A set of meteorological observations, as full as is practicable, should be taken on every garden. Rainfall, maximum and minimum temperatures, humidity are all easily measured. Soil temperature and sunshine records would follow. It is only in this manner that knowledge concerning weather and crop which is now vague and unconscious can be co-ordinated and correlated.

References.

(1) Blanford—Tables for the Reduction of Meteorological Observations.

(2) Carpenter and Cooper—Cultivation during the Rains. Ind. Tea Assoc., Sci. Dept., Quarterly Jour., part I, 1922.

(3) Eliot—Instructions to Observers of the Indian Meteorological Department.

(4) Harler—Meteorological Observations in Assam. Ind. Tea Assoc., Quarterly Jour., part I, p. 11, 1922.

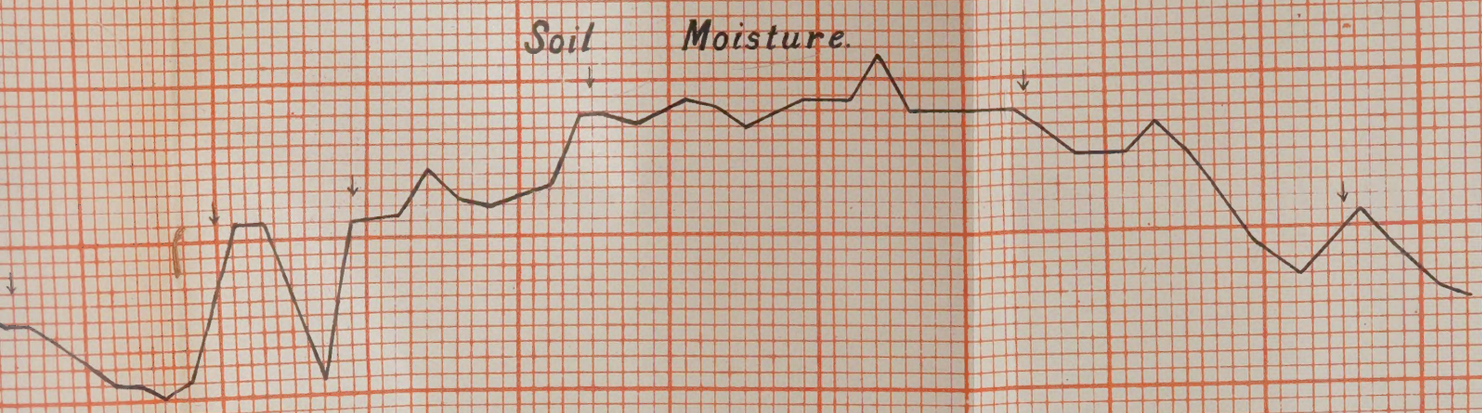
(5) Hope—Experiments on the Quality of Tea. Published by Ind. Tea Assoc.

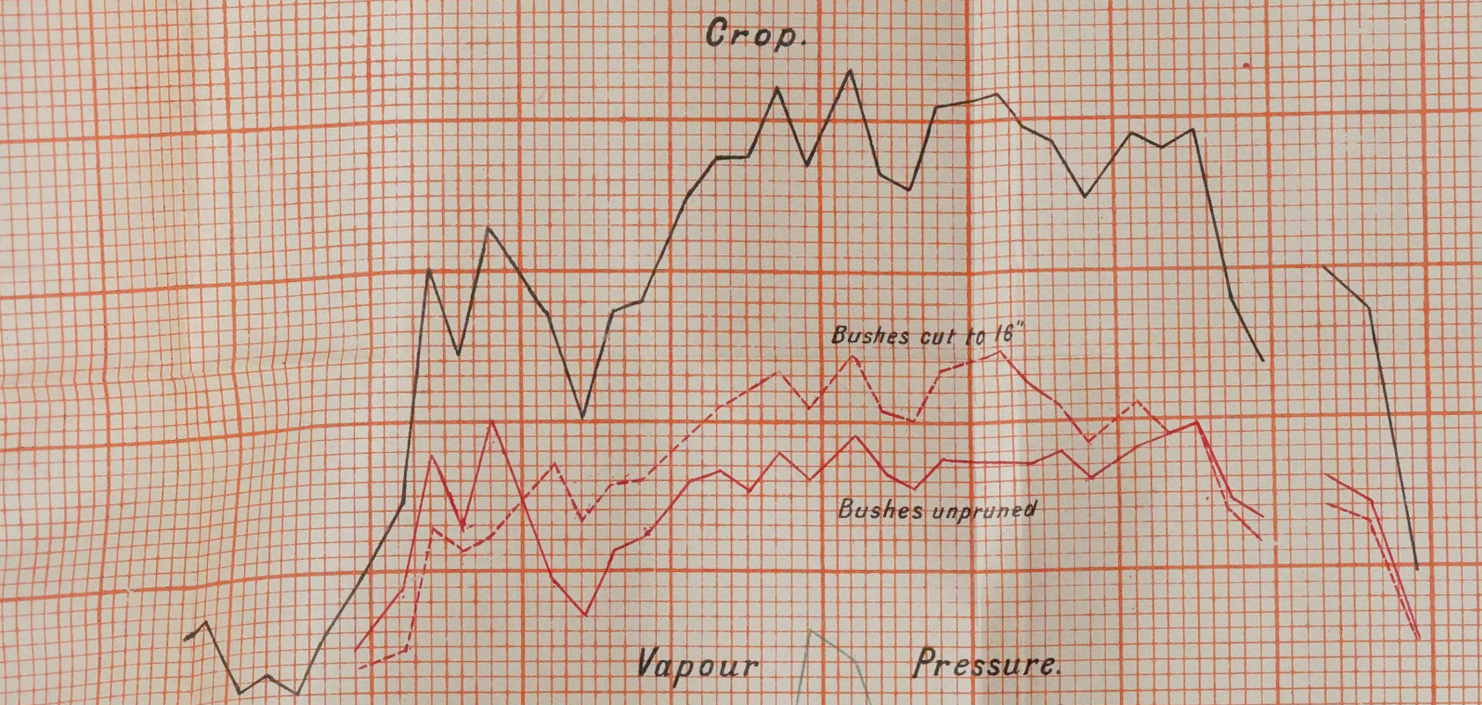
(6) Lehenbaure—Int. Rev. Sci. Prac. Agr. Year XII, No. 8, p. 934, August 1921.

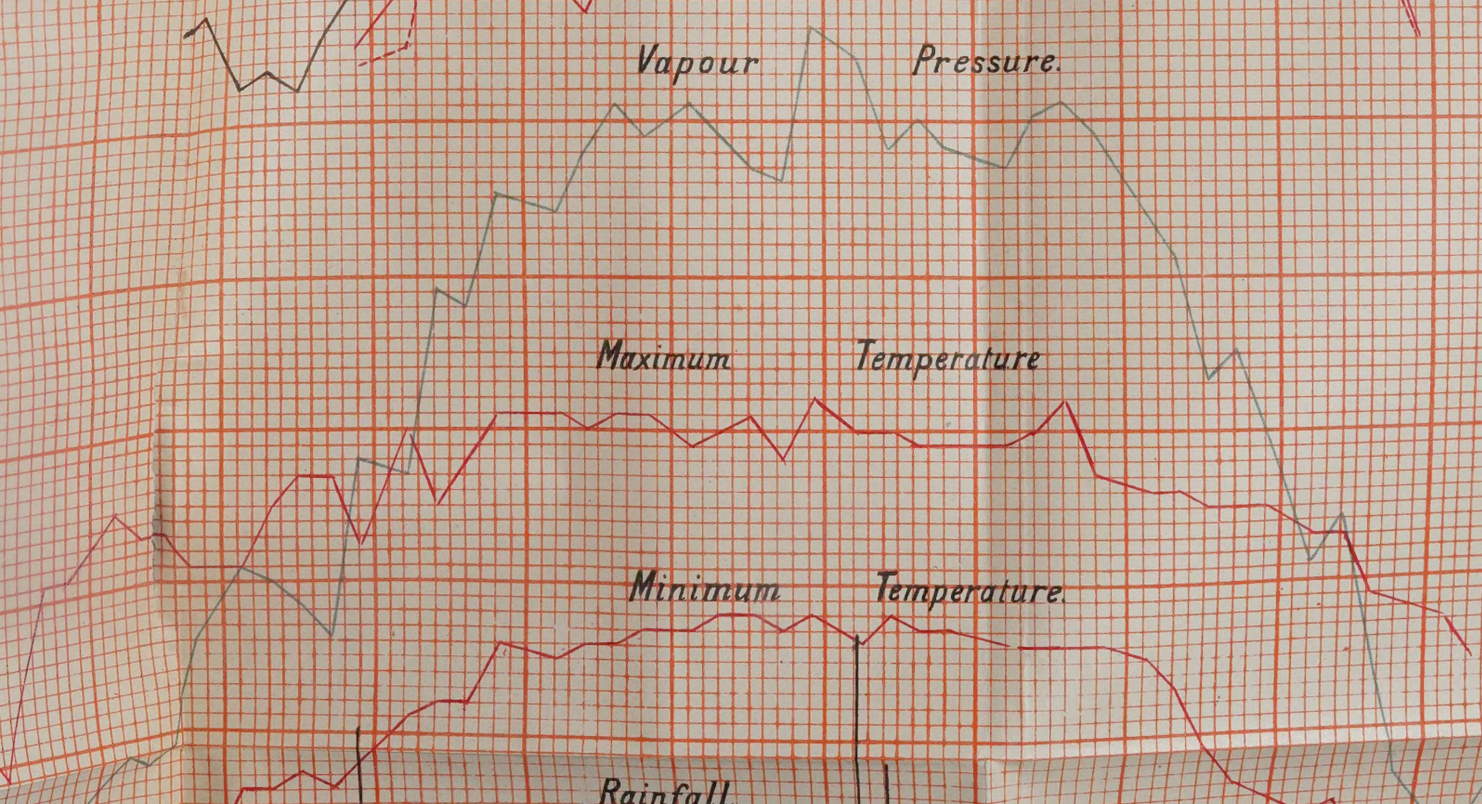
(7) Meteorology and Agriculture—Jour. Min. Agr., Vol. XXIX, No. 5, p. 432, August 1922.

SEASON 1922.

UARY. 19 26 | MARCH. 5 12 19 26 | APRIL. 2 9 16 23 30 | MAY. 7 14 21 28 | JUNE. 4 11 18 25 | JULY. 2 9 16 23 30 | AUGUST. 6 13 20 27 | SEPTEMBER 3 10 17 24 | OCTOBER. 1 8 15 22 29 | NOVEMBER. 5 12 19 26 | DECEM 3 10 17







NOTES.

A Note on the use of Perman's Expressor.—During the rains when the atmosphere is very humid it is often impossible to wither tea leaf sufficiently before it goes sour. In many cases expressors are employed, and although by this means the degree of the wither is not altered, rolling is facilitated.

What shall be done with the expressed juice and how much valuable matter does it contain are important questions. The first question was discussed in part II of the Scientific Department Quarterly Journal for 1922 and it was stated that the juice may be used by putting on leaf which is just going to be fired. The juice, after expression, should not be kept till the leaf from which it is obtained is ready for firing.

Samples of expressor juice from a Darrang Tea garden were analysed for total solids and tannin content. The leaf expressed had been withered to different degrees. The analyses were as follows :—

Sample :—Kutcha leaf (19 hours)—

Tannin	...	0·257 lbs. per gallon.
Total solids	...	0·96 lbs. ,,

Sample :—10-anna wither (20 hours)—

Tannin	...	0·294 lbs. per gallon.
Total solids	...	1·25 lbs. ,,

Sample :—14-anna wither (19 hours)—

Tannin	...	0·350 lbs. per gallon.
Total solids	...	1·41 lbs. ,,

Thus the richness of the expressed liquor increases with the completeness of the wither.

The actual loss made on the output of finished tea by using the expressor and discarding the juice may easily be calculated.

Thus, considering the highest value, 1·41 lbs. total solids, and assuming that a maund of leaf yields $\frac{3}{4}$ gallon juice and makes 32 lbs. finished tea (this assumes the leaf before rolling to contain 60% moisture), then the loss per 32 lbs. tea will be 1·05 lbs. or just over 3%. This value corresponds with observations made in factories in other parts of Assam.

With kutcha leaf taking the moisture content of the leaf before rolling at 75%, the loss per maund finished tea would be 3·6%.

C. R. H.

C. O. P.—1,500—22-2-1923.